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BEFORE THE ARIZONA CORPORATION COMMISSION

COMMISSIONERS

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Arizona Corporation Commission
DOCKETED
JUN 24 2016
DOCKETED BY

IN THE MATTER OF THE APPLICATION OF TUCSON ELECTRIC POWER COMPANY FOR APPROVAL OF ITS 2016 RENEWABLE ENERGY STANDARD IMPLEMENTATION PLAN.	DOCKET NO. E-01933A-15-0239
IN THE MATTER OF THE APPLICATION OF TUCSON ELECTRIC POWER COMPANY FOR THE ESTABLISHMENT OF JUST AND REASONABLE RATES AND CHARGES DESIGNED TO REALIZE A REASONABLE RATE OF RETURN ON THE FAIR VALUE OF THE PROPERTIES OF TUCSON ELECTRIC POWER COMPANY DEVOTED TO ITS OPERATIONS THROUGHOUT THE STATE OF ARIZONA AND FOR RELATED APPROVALS.	DOCKET NO. E-01933A-15-0322 **ARIZONA PUBLIC SERVICE COMPANY'S NOTICE OF FILING DIRECT TESTIMONY**

Arizona Public Service Company (APS) provides notice of filing of prepared Direct Testimony of Ahmad Faruqui and Charles A. Miessner of behalf of APS in the above-docketed proceeding. Note that Attachment AJF-3DR to the Direct Testimony of Ahmad Faruqui is being filed in static, written form, but is intended to be a working Excel spreadsheet. Accordingly, APS will be serving a live, functional spreadsheet to ACC Staff, the Hearing Division, and all intervenors along with the testimony.

RESPECTFULLY SUBMITTED this 24th day of June 2016.

By: ______________________________
Thomas A. Loquvam
Attorney for Arizona Public Service Company

ORIGINAL and thirteen (13) copies of the foregoing filed this 24th day of June 2016, with:

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DIRECT TESTIMONY OF CHARLES A. MIESSNER

On Behalf of Arizona Public Service Company

Docket No. E-01933A-15-0322

June 24, 2016

Table of Contents

DIRECT TESTIMONY OF CHARLES A. MIESSNER ON BEHALF OF ARIZONA PUBLIC SERVICE COMPANY (Docket No. E-01933A-15-0322)

I. INTRODUCTION

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. Charles A. Miessner, 400 North Fifth Street, Phoenix, Arizona 85004.

Q. BY WHOM ARE YOU EMPLOYED AND IN WHAT CAPACITY?

A. I am the Manager of Rates for Arizona Public Service Company (APS).

Q. WHAT ARE YOUR PROFESSIONAL QUALIFICATIONS?

A. My qualifications are provided in Attachment CAM-1DR, Statement of Qualifications.

II. PURPOSE OF DIRECT TESTIMONY

Q. WHAT IS THE PURPOSE OF YOUR DIRECT TESTIMONY IN THIS PROCEEDING?

A. The purpose of my Direct Testimony is to evaluate the residential rate designs proposed by Tucson Electric Power Company (TEP) for their efficiency and appropriateness in recovering costs, and for setting an effective platform to incent new technologies in the home. I will specifically comment on the proposed three-part rate that incorporates a service charge, energy charge, and demand charge.

III. SUMMARY OF DIRECT TESTIMONY

Q. PLEASE SUMMARIZE APS'S POSITIONS IN THIS RATE CASE.

A. In my Direct Testimony I provide APS's key positions in this case which include the following:

- TEP's current residential rates, like most utilities in the country, are misaligned with the costs of the services provided to customers, because they recover grid investment costs like power plants, power lines, substations, transformers, and other investments with volumetric kWh charges, instead of kW demand charges or monthly service fees, which would be more appropriate.

- Residential rates should be reformed to three-part demand rates, consistent with the rates for businesses, schools, government customers, and manufacturing facilities, where basic service costs are billed with a monthly service charge, energy costs, such as fuel, are billed with a kWh charge and the grid infrastructure costs are billed with a kW demand charge.

- The benefits of three-part demand rates include:

  1) Better price signals that enable new home technologies to be used as a resource to offset future grid costs;

  2) More efficient use of and funding for the grid;

  3) Better alignment of customer bill savings with utility cost savings, which reduces adverse impacts on other customers; and

  4) Rates that are fairer for all customers because they better reflect the costs of the services provided.

- Three-part demand rates can work for residential customers. APS has successfully implemented a demand rate for residential customers for 35 years.

- TEP's requested revisions to residential rates, which include increasing monthly service charges, revising kWh charges, implementing two optional demand rates, and requiring partial requirements customers with on-site generation to be served under a demand rate, will improve the alignment between rates and costs.

- APS supports TEP's proposed rates and requests that the Arizona Corporation Commission (ACC) approve them.

IV. RESIDENTIAL RATE REFORM

Q. WHY DID THE INITIAL TWO-PART RATE DESIGN BECOME THE PREDOMINANT RATE DESIGN?

A. Today most, if not all, electric utilities have residential rates that are not aligned with the types of costs necessary to serve the customers. Rather they reflect old, outmoded designs that may have made sense in the past when metering technology was limited and customers had no interest in or options to invest in distributed technologies. The current residential rates at TEP, although typical of electric utilities across the country, are based on decades-old designs that were developed when metering equipment was limited and customers had few, if any, options to invest in (what is now referred to as) distributed technologies. However, today's Automated Metering Infrastructure (AMI) or Automated Meter Reading systems (AMR) offer significant flexibility in residential rate design and allows energy usage information to be integrated with home controls and smart appliances.[1] Also today, customers have meaningful opportunities to invest in distributed generation, energy storage, electric vehicles, smart thermostats and appliances, home energy controls, advanced HVAC systems and other new technologies.

Q. DO TWO-PART RATE REFLECT THE COSTS INCURRED OR SERVICES PROVIDED BY THE UTILITY?

A. No. For example, utilities provide much more than just the commodity of electricity – they also provide basic services such as metering, billing, customer service and access to the grid, a demand or capacity service for the grid infrastructure investments like power

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[1] Three-part demand rates can be implemented without AMI through solid state digital meters that are manually read each month.

plants, transmission lines, substations, and local distribution equipment necessary to serve the customer's load, in addition to an energy service for the fuel and other variable costs for the actual electricity consumed in a month.

The rates for these individual services should reflect the unique costs to provide them, or cost of service. For example, the grid infrastructure is constructed to accommodate the customer's maximum electrical draw or "demand" in any hour, as measured in kW, not the total monthly energy consumption, which is measured in kWh. However, the old two-part, volumetric, rate structures that include only a monthly service charge and a kWh charge are misaligned with the utility's costs to serve customers because they recover all of the grid infrastructure costs and some of the basic service costs with a volumetric kWh energy charge, instead of a kW demand charge and a more appropriate monthly service fee. By doing so, the charges on the bill do not accurately reflect either the services provided to the customer or the cost of those services.

Q. WHY MUST RESIDENTIAL RATES BE REFORMED?

A. Under a two-part volumetric rate, the customer's bill savings are only linked to the utility's kWh energy costs, such as fuel, and not the demand-related grid investment costs. This misalignment of rates and costs results in unfunded grid costs being shifted to other customers in the form of higher rates. Two-part volumetric rate designs are also economically inefficient and ineffective in reducing a utility's total costs to serve, and ultimately unfair to customers. They are inefficient because they do not provide the right price signals for when and how customers use electricity. Nor do they provide the correct incentives for customers desiring to invest in distributed technologies because such technologies will not be rewarded for reducing demand-related grid costs. Both of these issues will result in the inefficient use of, and inadequate funding for, the grid.

In addition, for similar reasons, the two-part volumetric rates are also ineffective in reducing a utility's overall costs because they do not effectively incent customers to lower their monthly demand. As a result, the rates would likely only reduce the utility's energy-related costs, like fuel, and not the demand-related costs, which include all of the extensive grid investment costs.

Q. WHAT ARE THE BENEFITS OF RATE REFORM?

A. Reforming residential rates from two-part energy rates to three-part demand rates will better align rates with the costs of the services provided by the utility. This improved alignment has a number of benefits. It will incent the right type of home technologies; provide accurate price signals for incenting how and when customers use electricity; accurately reflect the types of services provided by the utility and the costs for those services; and provide opportunities for customers to save on their bills without shifting costs to other customers. All of these factors will result in the improved use of, and funding for, the electrical grid.

In addition, the two-part volumetric rate only provides one opportunity for customers to save on their bill – by reducing their total kWh consumption. In contrast, a three-part rate rewards customers for reducing both their energy and their demand. Furthermore, under the three-part rate, the bill savings for the demand and energy charges will have an actual connection to reductions in both the utility's grid costs and energy costs, thus minimizing any adverse impacts on other customers.

Q. HOW ARE TYPICAL RESIDENTIAL RATES AND COSTS CURRENTLY MISALIGNED?

A. Residential rates and costs are currently misaligned because they rely on volumetric kWh energy charges to recover grid investment costs – wires, poles, transformers, and generating plants, which are by far the predominant costs to serve residential customers. In contrast, these grid costs are recovered through the more appropriate kW demand charges and monthly service charges for most non-residential customers like businesses, schools, colleges, hospitals, fast-food restaurants and government buildings.

Q. WHAT IS THE DIFFERENCE BETWEEN DEMAND AND ENERGY?

A. Energy is the total consumption of electricity over a billing month, measured in kWh (1,000 Watt-hours). Demand is the instantaneous electrical draw of a customer's load at a single point in time, measured in kW (1,000 Watts). If you turned on ten 100-Watt lightbulbs at the same time they would draw (or demand) 1 kW at that instant. If you left them all on for 5 hours they would consume 5 kWh of energy (1 kW used over 5 hours).

Q. WHY IS THIS DISTINCTION IMPORTANT?

A. Demand and energy drive different costs, both of which are necessary to serve customers. The size of the grid necessary to serve the home is driven by the home's kW demand. This includes infrastructure investments in power plant capacity, wires, poles, substations, transformers and other capital equipment. For example, a home that draws a maximum load of 8.0 kW in one hour requires 8.0 kW of grid investment to serve it, regardless of the overall energy consumption during the month.

Other costs, such as fuel and variable operation and maintenance costs are driven by a customer's total kWh energy consumption during the month. In this same home, the customer's average load over all of the hours in a month may be more like 2.5 kW per hour, which would equate to 1,825 kWh (2.5 kW times 730 hours in a month).

Suppose the customer goes on vacation for two weeks and reduces their monthly kWh energy consumption, but still drew 8.0 kW demand sometime during the other two weeks. What costs would they reduce? They would certainly reduce the fuel and other variable costs needed to serve them because of the reduction in monthly kWh consumed. However, they would still require 8.0 kW of grid services for the home because they still drew 8.0 kW demand in some hour before or after the vacation. Stated another way, the fixed infrastructure does not go away just because the customer leaves for a couple of weeks.

Q. HOW DOES THIS TRANSLATE TO THE RATES?

A. A utility provides the customer with three fundamental types of services: basic services for connection to the grid each month, kWh energy, and kW demand. Business customers, except for extremely small accounts, are charged separately for these services through a three-part demand rate. The customer pays for basic services through a monthly service charge, energy services through a kWh energy charge, and demand services through a kW demand rate. In contrast, residential customers have historically been billed through a two-part volumetric energy rate, where the energy services, demand services, and some of the basic services are billed with a kWh energy charge, and a portion of the basic services with a monthly service charge.

V. <u>APS'S EXPERIENCE WITH RESIDENTIAL THREE-PART DEMAND RATES</u>

Q. WHAT IS APS'S EXPERIENCE WITH RESIDENTIAL DEMAND RATES?

A. APS has significant experience with residential three-part demand rates. We currently have about 120,000 customers, or 12% of our total customers, on a demand rate.

Q. HOW LONG HAS APS OFFERED THESE RATES?

A. APS has offered residential demand rates for 35 years.

Q. WHY WERE DEMAND RATES FIRST ADOPTED?

A. APS's earliest three-part demand rates date back to 1981. In approving the rate at that time, the Arizona Corporation Commission (ACC) stated that a residential rate based primarily on each customer's kWh energy consumption "ignores the fact that the cost of providing electric service is increasingly a function the demand for electricity places on the system rather than total power consumed."[2] The Commission further recognized that including a demand component in residential customers' bills would provide "an incentive to customers to manage their electric load in a manner that can result in lower electric bills for the individual customers and equally important, a reduction in APS peak demand which can have the effect of reducing the need for expensive additional generating facilities."[3]

Q. CAN CUSTOMERS RESPOND TO DEMAND CHARGES?

A. Yes. While the experience varies for each customer, APS has found that customers can respond to demand charges and lower both their monthly demand and energy. Many customers may be generally aware of the demand charge on their bill and can try to reduce it by changing their energy usage behavior and patterns, such as avoiding using major appliances at the same time to lower the home's maximum electrical draw. Some customers may wish to further enhance their experience and bill savings by actively managing their demand through investments in home energy controls, efficient appliances, HVAC systems and other devices. Then there are some customers who may not be interested in any of the specific components of the electric bill, including the demand charge; they are more likely to be primarily concerned that the total bill seems to be reasonable and comports to some typical expected amount. These latter customers may have a more limited knowledge of demand, energy, or even the service charge component of the bill, and may not try to actively manage any of them. However, some

[2] Decision No. 51472 (Oct. 21, 1980) at Finding of Fact 1.
[3] *See id.* at Finding of Fact 3.

of these customers end up saving on their bill under a demand rate because their customary electrical usage patterns naturally benefit from a demand charge. For example, they may have a lower maximum kW demand during the month in relation to their monthly kWh energy consumption.

Q. DO CUSTOMERS HAVE TO INVEST IN ENERGY TECHNOLOGIES OR EMPLOY SOPHISTICATED PLANNING TO RESPOND TO DEMAND RATES?

A. No. Customers can respond to demand charges by employing simple strategies on how they use their major appliances such as the water heater, clothes dryer, dishwasher, electric oven and cooktop. For example, these appliances could be used during the off-peak hours, which would completely eliminate any associated demand, or the customer could stagger the use of these appliances and not use them at the same time, which would lower, but not eliminate, the demand. These strategies would not require any sophisticated planning, special meter data, or investment in controls, special appliances or other equipment.

Additionally, as a second step, customers can utilize relatively inexpensive timers and controls to help manage their monthly demand. Therefore, demand charges do not require the customer to employ sophisticated strategies or invest in expensive technology in order to respond to the rates and save on their bill.

Q. CAN DEMAND CHARGES WORK FOR ALL SIZES OF CUSTOMERS?

A. Yes. Demand charges can work for customers of all sizes, from apartments to large homes. It is the relative relationship between demand and energy that matters, in terms of bill savings, not the absolute size of the monthly energy usage. For example, an apartment will typically have a small kWh energy consumption as well as a small kW demand, while larger homes will have relatively higher kWh and kW.

While the current participants in APS's demand rates on average are larger than the average customer, in terms of monthly kWh consumption, there are many small and medium size participants as well. It's no different than business customers, where APS has three-part demand rates for all sizes of customers ranging from small convenience stores to large manufacturing facilities,

Q. WHAT KIND OF DEMAND SAVINGS HAVE CUSTOMERS ACHIEVED?

A. Again, it varies by home. We looked at a large group of customers that switched from a two-part time-of-use energy rate to the three-part time-of-use demand rate and found that about 60% saved on their demand and energy, and those that actively manage their demands have achieved demand savings of 10% - 20% or more. On average, customers on the three-part rate reduce their monthly demand by 3% to 4% depending on the season. These customers also tend to save on their on-peak and monthly kWh usage after switching to the three-part demand rate.

Q. HAVE CUSTOMERS ON DEMAND RATES SAVED ON THEIR BILL?

A. Typically, yes. Looking at this same sample of customers we found that over 90% of the customers that switched to the demand rate saved on their monthly bill. The average bill savings was 9%, and the top 25% saved over 20% on average (excluding taxes and adjustments). Some of the best savers were the small and medium-size usage customers.

Q. WHAT CAUSES THESE BILL SAVINGS?

A. The three-part demand rate structure rewards customers for reducing both their demand and energy. Because APS's demand rate is a time-of-use rate, it also provides savings for shifting usage to the off-peak hours. In essence, APS's three-part demand rate provides customers three opportunities to save on their bill. In comparison, our two-part inclining block volumetric rate only provides one opportunity to save – namely, reducing the total monthly kWh energy usage.

Q. IS THIS A WIN-WIN SITUATION OR ARE THESE BILL SAVINGS SHIFTED TO OTHER CUSTOMERS?

A. It's a win-win situation. As discussed earlier, when customers reduce their demand and energy, they reduce both the grid investment costs and the fuel and other variable costs necessary to serve them. Because the bill savings from the reduced demand and energy charges are directly aligned with the demand-related and energy-related costs to serve the customer, there are few, if any, costs shifted to other customers. Simply stated, the bill savings better match APS's cost savings with a three-part rate.

In contrast, a two-part volumetric rate only incents customers to reduce their monthly kWh consumption, not their demand. In this case, only the fuel and other variable costs are reduced, typically not the grid investment costs. But customers are rewarded as if they had reduced both types of costs.

VI. TEP'S RESIDENTIAL RATES AND COST RECOVERY

Q. PLEASE DESCRIBE TEP'S RESIDENTIAL RATES.

A. TEP's current residential rates are based on the two-part volumetric rate, which includes a monthly service charge and kWh energy charges. The service charge is a flat amount per month. The kWh energy charges have two varieties – an inclining block and time-of-use structure. Most TEP customers are on the inclining block rate.

Q. PLEASE SUMMARIZE TEP'S COSTS TO SERVE RESIDENTIAL CUSTOMERS.

A. The cost of service study provided in standard filing requirement "G Schedules" and other relevant information show that TEP's costs to serve residential customers include generation, power supply and fuel costs, transmission infrastructure investments and ancillary services, local grid infrastructure cost for delivering the energy to the home and hookup costs such as some secondary service costs, meters, meter reading, billing and customer care.

Q. ARE TEP'S CURRENT RESIDENTIAL RATE STRUCTURES ALIGNED WITH THEIR COST OF SERVICE?

A. While the overall proposed level of cost recovery for each residential rate class appears to be generally consistent with the class cost of service, the current residential rate structures do not align rates with the costs to serve individual customers as well as they could with three-part demand rates. Specifically, TEP's two-part volumetric rate structure recovers grid infrastructure investments through volumetric kWh charges, even though the costs are determined by the size of the home's electrical draw (or demand), not the monthly kWh consumption. Likewise, even some of the basic service costs also are recovered through kWh charges.

Q. WHAT CHANGES DOES TEP PROPOSE IN THIS RATE CASE?

A. TEP proposes to (1) increase the monthly service charge, (2) revise the kWh charges in the inclining block rate and eliminate the third and fourth blocks and (3) offer two new three-part demand rates.

Q. DO YOU BELIEVE THESE CHANGES WILL IMPROVE THE ALIGNMENT OF TEP'S RESIDENTIAL RATES WITH COSTS?

A. Absolutely.

Q. PLEASE EXPLAIN.

A. I believe TEP's proposed revisions to its residential rates will result in substantial improvements in aligning the rate structures with costs and to the services provided. For example, the proposed rate revisions improve the basic service costs that are recovered through the monthly service charge, rather than through a kWh energy charge, for all residential rates. They also eliminate the highest tail block kWh charges in the inclining block rate to better reflect cost of service. And they introduce two three-part demand rate options consistent with the type of design that I detailed in the rate reform discussion. These new rates recover basic services with a monthly service charge, demand services with a kW demand charge, and energy services with a kWh energy charge, which results in bills that are more aligned with the costs and services provided.

Q. WHAT ARE THE BENEFITS OF THESE PROPOSED CHANGES?

A. As discussed above, rate structures that are better aligned with costs will provide much better price signals for customers that wish to invest in distributed technologies, smart appliances and energy controls in their home, and result in a more efficient use of, and funding for, the grid. In particular, the three-part demand rate will provide an opportunity for customers to save on both the demand and energy components on their bill. These bill savings will be aligned with a reduction in TEP's demand and energy-related costs, which will mitigate potential adverse impact on the rates of other customers.

Q. DOES TEP PROPOSE MANDATORY DEMAND CHARGES FOR ALL RESIDENTIAL CUSTOMERS?

A. Not at this time. In this rate case, TEP proposes that the three part demand rate be mandatory only for partial requirements customers with on-site generation and optional for all other residential customers.

TEP acknowledges the benefits of three-part demand rates and expresses an interest in widely applying demand rates to residential customers in the future. However, in this rate case, they appear to focus on improving the recovery of fixed costs primarily through an increase in the monthly service charge, the introduction and promotion of optional demand rates, and the implementation of mandatory demand rates for partial requirements customers.

Q. DOES APS SUPPORT THIS PROPOSAL?

A. Yes. While APS believes that it is reasonable and fair to apply demand rates to all residential customers, we believe that TEP's proposal is appropriate at this time and takes a significant first step towards that objective. This is particularly true because TEP's proposal involves a mandatory demand rate for partial requirements customers.

Q. WHAT IS A PARTIAL REQUIREMENTS CUSTOMER?

A. A partial requirements customer has on-site generation, like rooftop solar, that supplies some of their generation service needs for their home or business, with the utility supplying the remaining services.

Q. WHICH SERVICES DOES THE UTILITY CONTINUE TO SUPPLY TO PARTIAL REQUIREMENTS CUSTOMERS?

A. As discussed above, we can generally think of utility services in three basic categories: fuel and energy-related services related to the customer's total monthly energy consumption; grid services, like power plants, transmission lines, substations and transformers, that are related to the customer's monthly kW demand; and basic services such as meters, billing, customer care, public benefits programs, and local equipment needed to hook the home up to the grid. Each of these general service categories can be further subdivided into more specific services. Table 1 provides an illustrative example of utility services and identifies the services that are typically self-provided by a partial requirements customer, and the services that are typically still provided by the utility.

As shown, the customer's on-site generator provides some of their fuel and generation capacity needs while the utility continues to provide the vast majority of services to the partial requirements customer.

Table1
Utility Services Self Provided by a Partial Requirements Customer

SERVICE	SELF PROVIDED	UTILITY PROVIDES
Fuel	X	X
Power plant capacity	Partial	X
Reliability backup		X
Grid power to start and run major appliances		X
Transmission and ancillary services to run the grid		X
High voltage power delivery		X
Transformation		X
Local power delivery		X
Grid facilities for two-way power flow		X
Grid hookup equipment		X
Metering and billing		X

Customer care		X
Public benefits programs		X

Q. DOES APS BELIEVE THAT IT IS APPROPRIATE TO APPLY DEMAND RATES TO PARTIAL REQUIREMENTS CUSTOMERS?

A. Yes. In fact, three-part demand rates are essential for partial requirements customers to ensure that they pay for the services that they receive from their utility. Under two-part rates, most of the services provided by the utility are billed under a kWh charge, which is based on the customer's total monthly energy usage. Therefore, if a customer significantly reduces their monthly kWh purchases from the utility by installing on-site generation, they would avoid paying for many of the services shown in Table 1 that they continue to receive from the utility. The costs for these services would ultimately be shifted to other customers.

For example, suppose a customer is served under a two-part energy rate and uses 7.0 kW demand and 1,500 kWh energy per month on average for their home. After installing rooftop solar they continue to draw 6.0 kW from the utility but reduce their energy purchases by 80%, down to 300 kWh per month. In this typical case, the customer would avoid paying for 80% of the costs for most of the services listed in Table 1, even though only the first item, fuel cost, is reduced due to the on-site generation.

Conversely, under a three part rate, the customer would continue to pay for the other services through the 6.0 kW times the demand charge and the monthly service charge. As a result, and assuming an appropriate level of demand charge, none of the bill savings would be shifted to other customers.

Q. DOES A SMALL APARTMENT OR OTHER SMALL USER ALSO SHIFT COSTS?

A. No, customers in small apartments are entirely different. As shown in Table 2, a small apartment without on-site generation may also only consume 300 kWh per month, but would draw a demand that is significantly lower than the 6.0 kW from the home with on-site generation. In fact, a demand of 2.0 kW per month would be more typical of an apartment this size. So the small apartment would require substantially less grid investment cost from the utility, which is driven by the kW demand, compared with the partial requirements home. However, under a two-part rate, the bill would be the same for both customers. Stated another way, the home with on-site generation would be paying the bill of a small apartment, but requiring the grid investment costs of a large home. Therefore, APS believes that it is both fair and appropriate to implement mandatory demand rates for partial requirements customers and, at this time, optional demand rates for other customers.

Table 2
Illustrative kWh Energy and kW Demand for Apartments vs Homes

	Monthly kW Demand from Utility	Monthly kWh Energy from Utility
Home without on-site generation	7.0	1,500
Home with on-site generation	6.0	300
Apartment without on-site generation	2.0	300

VII. CONCLUSION

Q. WHAT IS APS RECOMMENDING THAT THE COMMISSION DO?

A. APS recommends that the Commission approve TEP's proposed residential rate design.

Q. DOES THAT CONCLUDE YOUR DIRECT TESTIMONY?

A. Yes.

Attachment CAM-1DR

Summary of Qualifications

Charles Miessner
Statement of Qualifications

Charles Miessner has over 30 years experience in the electric utility industry in the areas of pricing, planning, and business development for both utilities and private energy companies. He currently serves as Manager of Rates at Arizona Public Service. Prior to joining Arizona Public Service he served in management and leadership positions for Progress Energy, Tucson Electric Power, AES - New Energy, New West Energy and The Salt River Project. His accomplishments include: developing, implementing and evaluating retail rates; developing integrated resource planning methods and models; and directing strategic planning. Charles has appeared before regulators and legislators on energy issues in Arizona, California, Nevada and New Mexico. He serves on the national rates committee for the Edison Electric Institute. Charles has a B.S. in Economics from Arizona State University and has completed all requirements, excluding dissertation, towards a PH.D. in Economics from the University of North Carolina.

DIRECT TESTIMONY OF AHMAD FARUQUI

On Behalf of Arizona Public Service Company

Docket No. E-01933A-15-0322

June 24, 2016

Table of Contents

DIRECT TESTIMONY OF AHMAD FARUQUI

ON BEHALF OF ARIZONA PUBLIC SERVICE

(Docket No. E-01933A-15-0322)

I. INTRODUCTION

Q. PLEASE STATE YOUR NAME, JOB TITLE, BUSINESS ADDRESS AND PARTY FOR WHOM YOU ARE FILING TESTIMONY.

A. My name is Ahmad Faruqui. I am a Principal with The Brattle Group. My business address is 201 Mission Street, Suite 2800, San Francisco, California 94105. I am filing testimony on behalf of Arizona Public Service Company (APS).

Q. PLEASE DESCRIBE YOUR PROFESSIONAL BACKGROUND AND EXPERIENCE.

A. I have 40 years of academic, consulting and research experience as an energy economist. During my career, I have advised 135 clients in the energy industry, including utilities, regulatory commissions, government agencies, transmission system operators, private energy companies, equipment manufacturers, and IT companies. Besides the US, my clients have been located in Australia, Canada, Chile, Egypt, Hong Kong, Jamaica, Philippines, Saudi Arabia, South Africa, and Vietnam. I have advised them on a wide range of issues including rate design, load forecasting, demand response, energy efficiency, distributed energy resources, cost-benefit analysis of emerging technologies, integration of retail and wholesale markets, and integrated resource planning. I have testified or appeared before several state, provincial and federal regulatory commissions and legislative bodies. I have been an invited speaker at major energy conferences in Africa, Asia, Australia, Europe, North America and South America. Finally, I have authored, co-authored or co-edited more than 150 articles, books, editorials, papers and reports on various facets of energy economics. More details regarding my professional background and experience are set forth in my Statement of Qualifications, included as Attachment AJF-1DR.

Q. WHAT ARE YOUR RESPONSIBILITIES AS A PRINCIPAL WITH THE BRATTLE GROUP?

A. I lead the firm's practice in helping clients understand and manage the changing needs of energy consumers.

Q. HAVE YOU PREVIOUSLY TESTIFIED BEFORE THE ARIZONA CORPORATION COMMISSION ("COMMISSION")?

A. Yes. I testified in the most recent UNS Electric rate case, Docket No. E-04204A-15-0142. I also recently submitted written testimony in the APS rate case on the 1st of June, 2016, Docket No. E-01345A-16-0036. I have also spoken at a technical workshop before the Commission on the 20th of March, 2014. My presentation discussed the impact of changing customer energy use patterns on utilities. The workshop was entitled, "In the Matter of the Commission's Inquiry into Potential Impacts to the Current Model Resulting from Innovation and Technological Developments in Generation and Delivery of Energy."[1]

II. <u>OVERVIEW AND ORGANIZATION OF TESTIMONY</u>

Q. WHAT IS THE PURPOSE OF YOUR DIRECT TESTIMONY IN THIS PROCEEDING?

A. The purpose of my testimony is to evaluate the merits of Tucson Electric Power's (TEP's) proposal to offer three-part rates to residential customers, including new net

[1] Docket No. E-00000J-13-0375, Substantive Workshop No. 1(a) Special Open Meeting, March 20, 2014.

metering distributed generation (DG) customers with rooftop photovoltaic (PV) panels.[2] The scope of my testimony is focused on the structure, advantages, and rationale for three-part rates. I do not address the specific prices that are being proposed or any other rate options that have been proposed by TEP.

Q. PLEASE SUMMARIZE YOUR TESTIMONY.

A. My testimony begins with a discussion of ratemaking principles and the necessity of replacing two-part rates with three-part rates. An overriding principle of electric rate design is that of cost causation, i.e., the structure of rates should follow the structure of costs. For a variety of reasons, the standard residential rate design in the United States has not followed this basic precept. A very large share of utility costs is fixed. Of the remainder, some vary with peak demand and some vary with energy consumption. Yet most of the fixed and demand-driven costs are recovered through volumetric rates (expressed in cents/kWh). It is possible that in response to rising energy prices, some customers might reduce the volume of electricity they consume but not reduce the demand they place on the grid, since they never see a price for demand. Consequently, much of the fixed costs required to meet their demand would go unpaid. The net result is that cost-causers would not pay for all of the costs they create. Those unrecovered costs would be shifted to customers who continue using an average amount of volume. This shift creates inequities and cross subsidies between customers.

This is a cost shift from lower load factor customers to higher load factor customers, and is a structural pricing inefficiency that can be ameliorated through a rate design that includes three parts: a fixed charge, a demand charge, and a volumetric charge. With a three-part rate design, customers would more efficiently use the electric grid in a way that would also reduce the cost shift because they are receiving more accurate price

[2] Throughout my testimony I refer to these customers as "rooftop solar" customers.

signals. In addition, demand rates would provide a price signal that would incentivize the introduction of technologies that reduce demand. If policy-makers wish to encourage innovative distributed technologies, demand rates offer an economically efficient and equitable method of doing so.

My testimony concludes by evaluating TEP's rate proposal in light of these principles. TEP has proposed the deployment of three-part rates. Based on my review, the proposed rates appear to be based on well-established principles of rate design and would make progress on the need to send a more accurate price signal to customers that encourages the adoption of new technologies that are most beneficial to the power system. Given the benefits of these new three-part rate designs, it would be reasonable to eventually make a demand charge a feature of the rate for all residential customers.

Q. HOW IS YOUR TESTIMONY ORGANIZED?

A. My testimony is organized into several sections. Section III reviews the principles of rate design and the advantages of three-part rates. Section IV summarizes TEP's rate design proposal and evaluates the proposal in light of the generally accepted ratemaking principles and the opportunities offered by three-part rates. Section V concludes the testimony.

Q. ARE YOU SPONSORING ANY ATTACHMENTS TO YOUR TESTIMONY?

A. Yes, I sponsor the following attachment to my testimony:

- Attachment AJF-1DR: Statement of Qualifications
- Attachment AJF-2DR: Summary of Residential Demand Rates
- Attachment AJF-3DR: Illustrative Example of Cross-Subsidy

III. PRINCIPLES OF RATE DESIGN

Q. PLEASE PROVIDE A HISTORICAL PERSPECTIVE ON THE THEORY OF ELECTRIC RATE DESIGN.

A. The principles that guide electric rate design have evolved over time. Many authorities have contributed to their development, beginning with the legendary British rate engineer John Hopkinson in the late 1800's.[3] Hopkinson introduced demand charges into electricity rates. Subsequently, Henry L. Doherty proposed a three-part tariff, consisting of a fixed service charge, a demand charge and an energy charge.[4] The demand charge was based on the maximum level of demand which occurred during the billing period. Some versions of the three-part tariff also feature seasonal or time-of-use ("TOU") variation corresponding to the variations in the costs of energy supply.[5]

In the decades that followed, a number of British, French and U.S. economists and engineers made further enhancements to the original three-part rate design.[6] In 1961, Professor James C. Bonbright coalesced their thinking in his canon, *Principles of Public Utility Rates*,[7] which was reissued in its second edition in 1988.[8] Some of these ideas were further expanded upon by Professor Alfred Kahn in his treatise, *The Economics of Regulation*.[9]

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[3] John R. Hopkinson, "On the Cost of Electricity Supply," *Transactions of the Junior Engineering Society*, Vol. 3, No. 1 (1892), pp.1-14

[4] Henry L. Doherty, *Equitable, Uniform and Competitive Rates,* Proceedings of the National Electric Light Association (1900), pp.291-321

[5] See, for example, Michael Veall, "Industrial Electricity Demand and the Hopkinson Rate: An Application of the Extreme Value Distribution," *Bell Journal of Economics*, Vol. 14, Issue No. 2 (1983).

[6] The most notable names include Maurice Allais, Marcel Boiteux, Douglas J. Bolton, Ronald Coase, Jules Dupuit, Harold Hotelling, Henrik Houthakker, W. Arthur Lewis, I. M. D. Little, James Meade, Peter Steiner and Ralph Turvey.

[7] James C. Bonbright, *Principles of Public Utility Rates*, (Columbia University Press: 1961) 1st Edition.

[8] James C. Bonbright, Albert L. Danielsen, and David R. Kamerschen, *Principles of Public Utility Rates,* 2nd ed. (Arlington, VA: Public Utility Reports, 1988).

[9] Alfred Kahn, *The Economics of Regulation: Principles and Institutions*, rev. ed. (MIT Press, June 1988).

Q. WHAT ARE THE GENERALLY ACCEPTED RATE DESIGN PRINCIPLES?

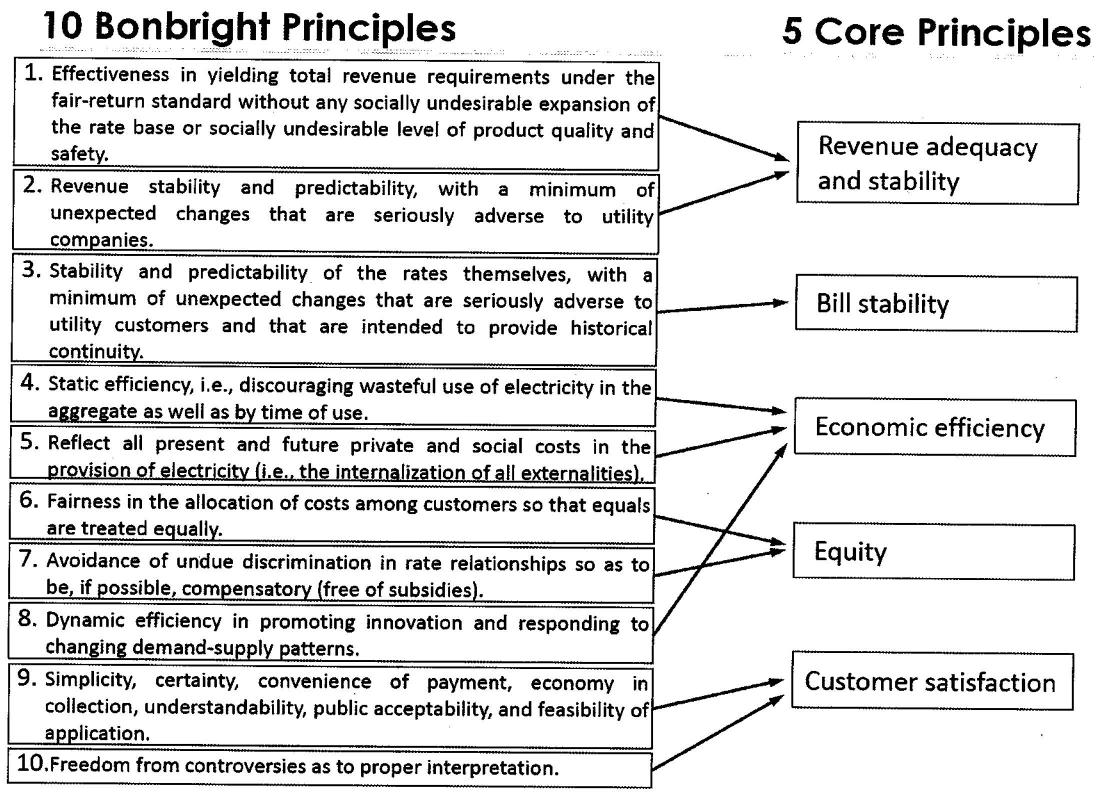
A. In the first edition of his text, Bonbright propounded eight principles which were expanded into ten principles in the second edition. These are almost universally cited in rate proceedings throughout the U.S. and are often used as a foundation for designing rates. For ease of exposition, I have grouped these into five core principles:

1. Economic Efficiency. The price of electricity should convey to the customer the cost of producing it, ensuring that resources consumed in the production and delivery of electricity are not wasted. If the price is set equal to the cost of providing a kWh, customers who value the kWh more than the cost of producing it will use the kWh and customers who value the kWh less will not. This will encourage the development and adoption of energy technologies that are capable of providing the most valuable services to the power grid, and thus the greatest benefit to electric customers as a whole.
2. Equity. There should be no unintentional subsidies between customer types. A classic example of the violation of this principle occurs under flat rate pricing structures (*i.e.*, cents/kWh). Since customers have different load profiles, "peaky" customers, who use more electricity when it is most expensive, are subsidized by less "peaky" customers who overpay for cheaper off-peak electricity. Note that equity is not the same as social justice, which is related to inequities in socioeconomic status rather than cost. The pursuit of one is not necessarily the pursuit of the other, and vice versa.
3. Revenue adequacy and stability. Rates should recover the authorized revenues of the utility and should promote revenue stability. Theoretically, all rate designs can be implemented to be revenue neutral within a class, but this would require perfect foresight of the future. Changing technologies and customer behaviors make load forecasting more difficult and increase the risk of the utility either under-recovering or over-recovering costs when rates are not cost reflective.

4. Bill stability. Customer bills should be stable and predictable while striking a balance with the other ratemaking principles. Rates that are not cost reflective will tend to be less stable over time, since both costs and loads are changing over time. For example, if fixed infrastructure costs are spread over a certain number of kWh's in Year 1, and the number of kWh's halves in Year 2, then the price per kWh in Year 2 will double even though there is no change in the underlying infrastructure cost of the utility.
5. Customer satisfaction. Rates should enhance customer satisfaction. Because most residential customers devote relatively little time to reading their electric bills, rates need to be relatively simple so that customers can understand them and perhaps respond to the rates by modifying their energy use patterns. Giving customers meaningful cost-reflective rate choices helps enhance customer satisfaction.

Figure 1 illustrates my grouping of Bonbright's original ten principles.

Figure 1: Deriving the Five Core Principles of Rate Design



Q. DID PROFESSOR BONBRIGHT DISCUSS THE CONCEPT OF COST CAUSATION IN DESIGNING RATES?

A. Yes. In the first edition, an entire chapter is devoted to this topic. It is entitled: "Cost of Service as the Basic Standard of Reasonableness." In the chapter, he states: "One standard of reasonable rates can fairly be said to outrank all others in the importance attached to it by experts and public opinion alike – the standard of cost of service, often qualified by the stipulation that the relevant cost is necessary cost or cost reasonably or prudently incurred."[10] Later, he states that "The first support for the cost-price standard is concerned with the consumer-rationing function when performed under the principle of consumer sovereignty."[11] He also cites another benefit of the cost-price standard

[10] James C. Bonbright, *Principles of Public Utility Rates*, (Columbia University Press: 1961) 1st Edition, Chapter IV, p. 67.
[11] Op. cit., p. 69.

when he says that "an individual with a given income who decides to draw upon the producer, and hence on society, for a supply of public utility services should be made to 'account' for this draft by the surrender of a cost-equivalent opportunity to use his cash income for the purchase of other things."[12] Later in Chapter XVI, where he discusses the "criteria of a sound rate structure," he says that a purely volumetric rate assumes that the total cost of the utility varies directly with the changes in the kWh output of energy. He calls this "a grossly false assumption" and says such a rate "violates the most widely accepted canon of fair pricing, the principle of service at cost." Later, while discussing the Hopkinson rate, he says that such a "rate distinguishes between the two most important cost functions of an electric-utility system: between those costs that vary with changes in the system's output of energy, and those costs that vary with plant capacity and hence with the maximum demands on the system (and subsystems) that the company must be prepared to meet in planning its construction program."[13]

Q. PLEASE DISCUSS FURTHER HOW THE CONCEPT OF COST CAUSATION FLOWS OUT OF THE BONBRIGHT PRINCIPLES.

A. The Bonbright principles of economic efficiency and equity in particular embody the concept of cost causation. Economic efficiency is achieved by having cost-reflective prices. This ensures that products are only consumed by those customers who value them at more than they cost to produce. Pricing below cost is wasteful because customers will purchase and consume products that they would not choose to consume if faced with the full cost. Similarly, pricing above cost is wasteful because customers who would get a net benefit from consuming the product at its cost of production lose out on that benefit. Respecting the equity principle requires that the tariff's design not result in unintended cross-subsidies between customers. This differs from a public policy that

[12] Op. cit., p. 70.
[13] Op. cit., p. 310.

seeks to intentionally subsidize certain customers through the tariff. Prices that are cost reflective minimize unintentional subsidies.

Q. GIVEN BONBRIGHT'S EMPHASIS ON COST CAUSATION IN SETTING UTILITY PRICES, WHY DOES HIS FIFTH PRINCIPLE CALL FOR REFLECTING SOCIAL COSTS (OR EXTERNALITIES) IN ELECTRIC RATES?

A. Each of Professor Bonbright's principles should be read in conjunction with the others. Reading a single principle in isolation from the others ensures that it will be taken out of context, resulting in an inaccurate and misleading use of his rate design philosophy. The cost of service is Professor Bonbright's *basic standard* for designing rates, and it is clear from his writings that above all, rates should be cost-based. This is easily squared with the principle of reflecting social costs in the provision of electricity. If a price has been assigned to a certain externality, in other words, if it has been internalized, and that price is part of the utility's cost structure, then it is economically efficient to reflect the price of that externality in rates for all customers. However, it would violate the core principles of ratemaking if only certain customers or technologies were charged or compensated for their impact on those externalities. For instance, compensating owners of only one specific technology for reductions in emissions would lead to inefficient levels of investment in that technology when there may be other options which, if similarly compensated, would provide even greater environmental benefits. All technologies and customers should be on a level playing field when developing residential rate design.

Q. WHAT IS THE STANDARD RATE STRUCTURE FOR RESIDENTIAL CUSTOMERS?

A. The standard rate structure for residential customers in much of the U.S. consists of two parts, a monthly service charge and a volumetric (kilowatt-hour, or kWh) energy charge. Most of the revenue is collected from the volumetric charge. The monthly service charge does not come close to reflecting the full amount of the fixed costs that are incurred in keeping a customer connected to the grid.

Q. DOES THE COLLECTION OF REVENUES ON A VOLUMETRIC BASIS ALIGN WITH THE ACTUAL INCURRENCE OF UTILITY COSTS?

A. No. The collection of utility revenues through volumetric charges does not comport with the underlying cost structure of providing electricity to customers. Most of the costs do not vary with the volume of electricity that is produced and delivered to the customer, but do vary with peak demand. And some are absolutely fixed, varying neither with energy consumed or peak demand.

It is well known that in order to provide electricity to a customer, a utility must bear – directly or indirectly – costs related to energy, generation, transmission, distribution, metering, and customer service. Generation energy costs vary with kWh electricity consumption. But generation capacity costs do not; they vary with system peak demand. Similarly, certain transmission costs vary with system peak demand, while distribution and other transmission costs vary with maximum demand that is local to the customer and to the neighborhood in which the customer resides. Metering, billing, customer care, and other connection/hookup costs are a fixed cost per each customer of a particular class. Some of these costs vary across time. Generation costs will vary from hour to hour depending on the marginal generation source. Distribution and transmission networks, while used year round, are generally sized to meet class and system peak demand, respectively.

Q. HOW SHOULD THESE COSTS TRANSLATE INTO RATES?

A. According to the notion of cost causation, the rate structure should reflect the nature of the costs. To address the deficiencies of current two-part rates, I support the institution of a three-part rate design, consisting of a fixed monthly service charge, a demand charge, and a volumetric charge. The fixed charge should be designed to at a minimum cover the fixed costs such as metering, billing, and customer care. Ideally, it should also cover the cost of the line drop and the associated transformer. The demand charge should be designed to cover demand-driven costs, such as transmission, distribution, and generation capacity. It is typically applied to the individual customer's maximum demand, either during a defined on-peak period, or regardless of time of occurrence, or a combination of the two. While the concept of demand is instantaneous, in implementation demand is usually measured over 15-minute, 30-minute or 60-minute intervals. The energy charge covers the cost of the fuels that are used to generate electricity, as well as power grid variable operations and maintenance (O&M). The demand charge and the energy charge might vary with the time of use of electricity and have different seasonal and/or peak/off-peak charges. Such three-part rates align the rate design with costs, a fundamental tenet of efficient rate design.

Q. WHAT IS THE CONSEQUENCE OF DEMAND-RELATED COSTS BEING COLLECTED THROUGH VOLUMETRIC RATES?

A. This mismatch between cost structure and rate structure creates an inevitable and indisputable cost shift from customers with lower load factors (i.e., high peak demand relative to total electricity consumption) to customers with higher load factors. Customers will reduce their load factor if, for instance, they install rooftop solar. With a lower load factor, customers paying for electricity under a flat volumetric rate design will reduce their bill without providing a proportionate reduction in system costs. Inevitably, customers with high (i.e., beneficial) load factors who are paying for electric service under a volumetric rate design wind up paying more for comparable service. This is inequitable.

To illustrate this point, I have created a simplified example with "Utility X" to show how two-part rates create cross-subsidies between customer classes. Utility X is authorized to collect $120 million in revenue per year from the 100,000 households in its service area. There are three types of households in this illustration: low energy usage households consume 500 kWh/month and are assumed to have a lower-than-average load factor,[14] standard energy usage households consume 1,000 kWh/month have an average load factor, and high energy usage households consume 1,500 kWh/month and have a higher-than-average load factor. This is shown in Table 1.

Table 1: Characteristics of Utility X

Input	Value	Units
Revenue Requirement	120,000,000	($/yr)
Households	100,000	(households)
Average Usage		
Low-users	500	(kWh/mo)
Standard-users	1,000	(kWh/mo)
High-users	1,500	(kWh/mo)
Load Factor		
Low-users	23%	%
Standard-users	27%	%
High-users	29%	%

Utility X collects its revenue requirement from customers with a two-part rate. Under its two-part rate, the utility collects ten percent of its revenue requirement with a fixed charge and ninety percent with a variable energy charge. However, the structure of Utility X's costs differs from its revenues. Fixed costs account for 25 percent of Utility

[14] Note that low energy usage does not necessarily correlate with low load factor. Load factor is the ratio of a customer's average and peak demand, and is independent of energy usage.

X's total costs, variable energy costs account for 25 percent, and demand-related costs account for 50 percent. Table 2 summarizes this common misalignment of costs and rates.[15]

Table 2: Revenue and Cost Structure for Utility X (per Customer)

	Revenue Structure	Cost Structure	Rate	Cost
Fixed	10%	25%	\$10 / mo	\$25 / mo
Variable	90%	25%	\$0.09 / kWh	\$0.025 / kWh
Demand	0%	50%	-	\$10 / kW

Table 3 illustrates how Utility X's two-part rate structure can create a cross-subsidy when households vary in consumptive use. In this example, low-usage/lower-load factor customers are subsidized by high-usage/higher-load factor customers. Low-usage customers benefit from a cross-subsidy because the revenue from their low monthly usage does not balance with the fixed costs and demand-related costs required to serve them. As a result, the high-usage customers in this example are on the hook for the subsidies to low-usage customers.

Table 3: Illustration of Cross-Subsidization Under a Two-Part Rate

Customer Class	Monthly Usage (kWh)	Demand (kW)	Load Factor	Fixed (\$/mo)	Variable (\$/mo)	Demand (\$/mo)	Monthly Bill (\$/mo)	Yearly Bill (\$/yr)	Number of Households	Total to Utility (\$/yr)
Standard household	**1,000**	**5.00**	**27%**						**33,333**	
Revenue				10	90	-	100	1,200		40,000,000
Cost				25	25	50	100	1,200		40,000,000
Over (Under) Payment				(15)	65	(50)	-	-		-
Low-usage household	**500**	**3.00**	**23%**						**33,333**	
Revenue				10	45	-	55	660		22,000,000
Cost				25	13	30	68	810		27,000,000
Over (Under) Payment				(15)	33	(30)	**(13)**	(150)		**(5,000,000)**
High-usage household	**1,500**	**7.00**	**29%**						**33,333**	
Revenue				10	135	-	145	1,740		58,000,000
Cost				25	38	70	133	1,590		53,000,000
Over (Under) Payment				(15)	98	(70)	**13**	150		**5,000,000**
Total				**(45)**	**195**	**(150)**	-	-	**100,000**	**120,000,000**

I have provided this illustrative cross-subsidy model as Attachment AJF-3DR, which also includes details on how cross-subsidization can be alleviated by appropriately matching Utility X's rates with its cost of service.

[15] Low-usage customers' demand is assumed to be 3 kW, standard-usage demand is assumed to be 5 kW, and high-usage demand is assumed to be 7 kW. These illustrative assumptions can be modified in the Microsoft Excel model, which has been provided as Attachment AJF-3DR.

Q. DID PROFESSOR BONBRIGHT SUPPORT THE USE OF THREE-PART RATES?

A. Yes. Professor Bonbright opposed largely volumetric rates since they treat "the total cost of the business as if it varied directly with changes in in the kilowatt-hour output of energy – a grossly false assumption – it violates the most widely accepted canon of fair pricing, the principle of service at cost."[16]

According to his widely cited text, Professor Bonbright believed that three-part rates mirrored the structure of utility costs and cited their widespread deployment to medium and large commercial and industrial rates.[17] In support of three-part rates, Bonbright cites an earlier text by the British engineer D. J. Bolton,[18] who states:

> "More accurate costing has shown that, on the average, only one-quarter of the total costs of electricity supply are represented by coal[19] or items proportional to energy, while three-quarters are represented by fixed costs or items proportional to power, etc. If therefore only one rate is to be levied it would appear more logical to charge for power and neglect the energy, were it not for certain practical difficulties of which the following are two. In the first place the effective power demand on the system made by any particular consumer is extremely difficult to estimate, and is very different from the individual maximum demand metered at the consumer's terminals. Secondly, a purely power tariff would probably lead to a waste of energy to a greater extent than a purely energy tariff leads to waste of power."[20]

Of course, with the arrival of advanced meters, customer demand at times of system and distribution peak can be accurately recorded. And the choice is no longer a binary one of imposing either an untimed demand-only rate or an energy-only rate. The time is ripe for

[16] James C. Bonbright, Albert L. Danielsen and David R. Kamerschen, Principles of Public Utility Rates, Second Edition, Public Utility Reports, Inc., 1988, p. 397.

[17] James C. Bonbright, *Principles of Public Utility Rates*, Columbia University Press, 1961.

[18] Bonbright says that "On many technical issues, no American treatise on electric utility rates can equal that by the distinguished British rate engineer D. J. Bolton." Page 289, n. 3.

[19] Coal was the dominant fuel for generating electricity in the United Kingdom in 1938 when the book was first published.

[20] D. J. Bolton, *Costs and Tariffs in Electricity Supply*, Chapman & Hall Ltd., 1951, p. 59.

deploying a three-part time-differentiated pricing structure that better reflects the cost of providing electric services in the TEP service territory.

Interestingly, when Bonbright discusses a two-part rate structure, he is referring to what he characterizes as "the two most important cost functions of an electric-utility system"[21] -- demand and energy charges. When he moves into a discussion of three-part rate structures, he adds truly fixed charges, customer charges, to the two-part rate concept. Beginning on page 346, three-part rates are discussed extensively in the Bonbright canon.[22]

Q. HOW HAS THE PRINCIPLE OF COST CAUSATION AND THREE-PART RATES BEEN APPLIED IN PRACTICE?

A. Many commercial and industrial (C&I) customers across the U.S. are served under three-part rate structures. Indeed, it can be said that those structures have been the norm for these customer classes for decades in much of the U.S.

In Arizona, for instance, other than a couple of small electric cooperatives, all utilities for which I was able to find rate information utilize demand charges for some or all of their C&I customers.[23] In fact, many U.S. utilities offer these rates on a mandatory basis to their medium and large C&I customers and a few, such as PacifiCorp's Utah service territory and Duke Energy's North Carolina service territory, offer them on a mandatory basis to even their smallest C&I customers.

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[21] Bonbright, p. 310.

[22] Bonbright, second edition, page 401, credits Doherty with extending the Hopkinson two-part rate into a three part rate. Henry L. Doherty, "Equitable, Uniform and Competitive Rates," Proceedings of the National Electric Light Association, 1900, pp. 291-321.

[23] The small utilities without demand charges are Columbus Electric Cooperative and Graham County Electric Cooperative. Both utilities sell less than 200,000 MWh of electricity per year.

Q. HAVE THREE-PART RATES BEEN OFFERED TO RESIDENTIAL CUSTOMERS IN OTHER U.S. JURISDICTIONS?

A. Yes. There are at least 20 utilities in 14 states that offer a three-part rate to residential customers, including APS, which has almost 120,000 of its customers on a three-part rate. In most cases, the rates are available to all customers on an opt-in basis. In the case of Salt River Project (SRP), a three-part rate is mandatory for all residential customers who choose to install a new rooftop solar system.[24] All residential customers of Mid-Carolina Electric Cooperative and Butler Rural Electric Cooperative also face a mandatory demand charge.

Q. WHAT HAS PREVENTED THREE-PART RATES FROM BEING MORE BROADLY DEPLOYED TO RESIDENTIAL CUSTOMERS?

A. Until recently, metering technology for residential customers has been a significant technological hurdle. The traditional electromechanical meters that were installed in most homes only measured the customer's cumulative electricity consumption and not the customer's demand. Without the ability to meter demand, utilities could not cost-effectively offer three-part rates to these customers. Advances in metering technology have changed this situation.

Q. HOW HAVE ADVANCES IN METERING TECHNOLOGY CHANGED THE UTILITY'S ABILITY TO OFFER THREE-PART RATES?

A. With the deployment of automated meters (sometimes also referred to as advanced metering infrastructure, or AMI), consumption can be recorded in intervals of an hour or less. This allows the utility to collect the consumption data necessary to incorporate demand charges into rates. It has removed a large barrier to the wider dissemination of cost-reflective rates to residential customers. Given these technological developments,

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[24] SRP website: http://www.srpnet.com/prices/home/customergenerated.aspx.

rate structures for residential customers should be changed where the necessary metering capability is in place.

Q. SHOULD UTILITIES OFFER THREE-PART RATES TO RESIDENTIAL CUSTOMERS?

A. Yes. The timing is propitious for making cost-reflective three-part rates the standard offering for all residential customers. These rates will recover costs from customers in an equitable manner by more accurately charging customers for their use of the power grid. A more cost-reflective rate will also encourage the adoption of emerging energy technologies and changes in energy consumption behavior that will lead to more efficient use of power grid infrastructure and resources.

Q. HOW WOULD A THREE-PART RATE ENCOURAGE THE ADOPTION OF EMERGING ENERGY TECHNOLOGIES?

A. By providing customers with a price signal that includes a component for demand, a three-part rate would encourage the adoption of technologies that are designed to smooth out a customer's load profile. Behind-the-meter battery storage, for example, could be used to release electricity during hours of high electricity demand and store electricity during hours of low electricity demand. Load control technologies, such as programmable communicating thermostats, demand limiters, and digital controls built into smart appliances, could also help customers manage their electricity demand. If a customer took service under a three-part rate, the use of battery storage, or other demand-reducing technologies, would reduce the customer's bill. This reduction in the customer's bill is an economic value that forms the basis of the price signal created by three-part rates.

In the same vein, introducing a demand charge and reducing the volumetric charge would appropriately decrease the economic attractiveness of energy technologies that cannot provide energy savings during those peak hours when the energy reductions are most valuable to the system. This simply means that the three-part rate structure is encouraging adoption of those technologies that are most beneficial to the power grid and to customers. It is important to take this broader view of energy technologies to avoid overstating the importance of one particular option that may not be the most beneficial.

Q. ASIDE FROM TRANSMITTING PRICE SIGNALS THAT ENCOURAGE TECHNOLOGICAL INNOVATION, WOULD THREE-PART RATES PROVIDE OTHER BENEFITS TO RESIDENTIAL CUSTOMERS?

A. Three-part rates will incentivize customers to smooth their energy consumption profile – and therefore reduce their electricity bills - even if they chose not to equip themselves with enabling technologies. There is a widespread misperception that customers do not respond to changing electricity prices. This is contradicted by empirical evidence derived from more than 40 pilots and full-scale rate deployments involving over 200 innovative rate offerings over roughly the past dozen years. The pilots have found that customers can and do respond to new price signals by changing their consumption pattern.[25]

Further, there is evidence that customers respond not just to changes in the rate structure generally, but specifically to demand charges. The following studies arrived at this conclusion after careful empirical analysis:

[25] Some of these studies are summarized in Ahmad Faruqui and Sanem Sergici, "Arcturus: International Evidence on Dynamic Pricing," *The Electricity Journal*, (August/September 2013). Similar results were obtained from an earlier generation of 14 pricing pilots that were funded in the late seventies and early eighties by the US Federal Energy Administration (later part of the Department of Energy). See Ahmad Faruqui and Bob Malko, "The Residential Demand for Electricity by Time-of-Use: A Survey of Twelve Experiments with Peak Load Pricing," *Energy*, Vol. 8, No. 10, (1983).

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- Taylor, Thomas N., 1982. "Time-of-Day Pricing with a Demand Charge: Three-Year Results for a Summer Peak." Award Papers in Public Utility Economics and Regulation. Institute of Public Utilities, Michigan State University, East Lansing, Michigan.
- Taylor, T., Schwartz, P., 1986, April. "A residential demand charge: evidence from the Duke Power time-of-day pricing experiment." *Energy Journal*. (2), 135–151.

Q. IS THERE ANY SPECIFIC ARIZONA EVIDENCE THAT CUSTOMERS WILL RESPOND TO DEMAND CHARGES?

A. Yes. As described in APS Witness Miessner's direct testimony in this proceeding, 60 percent of a sample of APS's customers on a three-part rate reduced their demand after switching to the three-part rate, with those who actively manage their demand achieving demand savings of 9 percent to 20 percent or more.[26] There is no reason to believe that TEP's customers will respond differently.

[26] See Direct Testimony of Charles Miessner at p. 9:26 - 27.

IV. TUCSON ELECTRIC POWER'S RATE PROPOSAL

Q. WHAT ARE TEP'S CURRENT RATES FOR RESIDENTIAL CUSTOMERS, AND HOW ARE THEY DESIGNED?

A. My understanding is that TEP's current residential rate offerings include Residential Electric Service ("R-01"), Residential Time-of-Use ("R-80"), and Residential Time-of-Use Super Peak ("R-8"). All three are two-part rates with a fixed monthly service charge and a volumetric charge. The Residential Electric Service option includes a $10 fixed monthly service charge and a four-tiered volumetric charge that varies seasonally (with lower volumetric charges in the winter). The other two options include a slightly higher fixed monthly service charge and a volumetric rate that varies both seasonally and by time of day.

Q. HOW IS TEP PROPOSING TO REDESIGN ITS RESIDENTIAL RATES?

A. TEP has proposed four specific changes to its residential rate offering: (1) Increasing the fixed monthly service charge, (2) reducing the number of tiers in the inclining block rate, (3) modifying the net metering payment policy for excess generation from rooftop solar, and (4) introducing two three-part rate options. The focus of my testimony is on the three-part rates that are being proposed.

Q. PLEASE DESCRIBE THE THREE-PART RATES THAT TEP HAS PROPOSED.

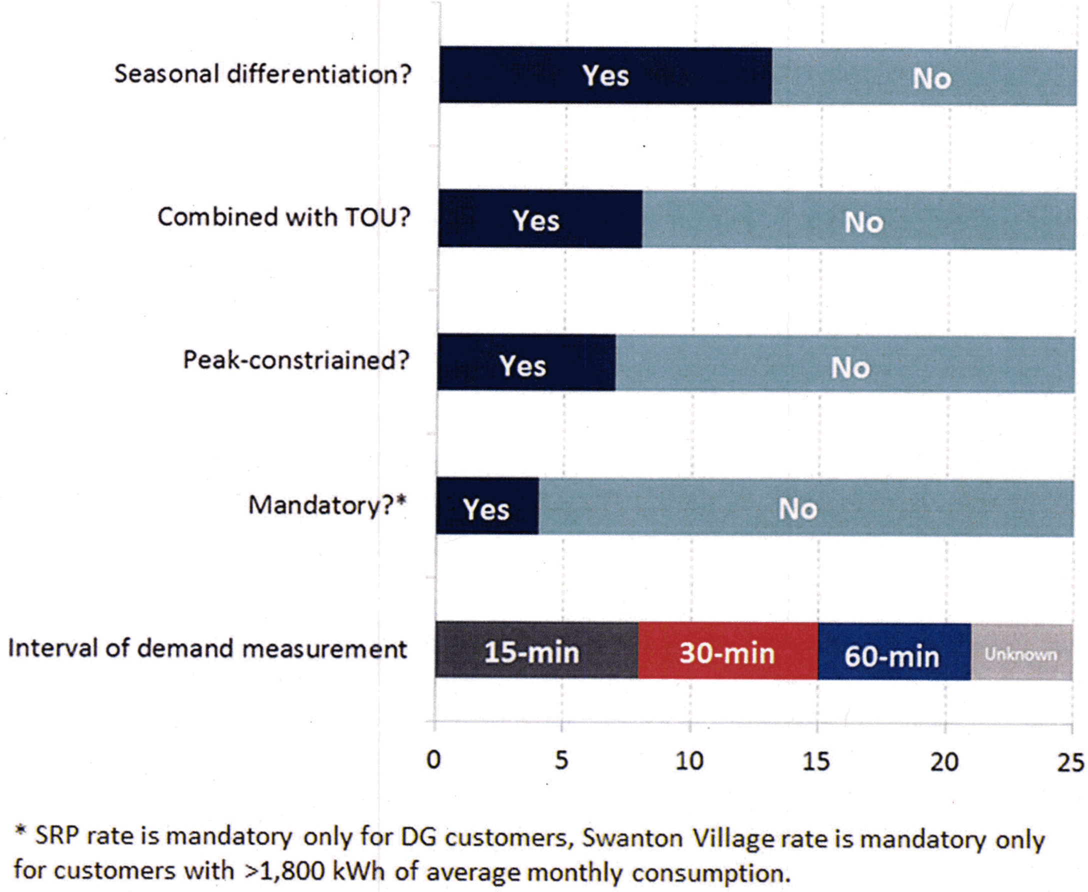
A. TEP has proposed two rates, one called "RES-D" and a second rate called "RES-D-TOU." Rooftop solar customers would have the option of enrolling in one of these two rates. Other residential customers would have these as options in addition to the standard residential rate options described previously (subject to the additional rate design changes that have been proposed by TEP).

My understanding is that the proposed RES-D rate includes a two-tier demand charge with a 7 kW threshold defining the tiers. The rate also includes a fixed monthly service charge of $20/month and a flat variable energy charge that is significantly lower than the volumetric charge in the existing two-part rates. Demand is measured as the customer's maximum one-hour demand in the billing month. The proposed RES-D-TOU rate has the same demand and fixed monthly service charges, but a time-varying energy charge which varies seasonally.

Q. HOW DOES TEP'S PROPOSED DEMAND CHARGE COMPARE TO THAT OF OTHER RESIDENTIAL THREE-PART RATE OFFERINGS?

The residential rate offerings of other U.S. utilities provide precedent for each of the elements in TEP's proposed demand charge. For instance, TEP is proposing to measure average demand over a 60-minute interval. Six of the residential three-part rates offered by U.S. utilities measure demand over a 60-minute interval. Figure 2 below describes how the existing residential demand rate offerings in the U.S vary across each key demand charge design element. Further information about all of the residential demand charge offerings in the U.S. that I have identified is provided in Attachment AJF-2DR.

Figure 2: Distribution of Features Across 25 Residential Demand Charge Offerings



Q. ARE TEP'S PROPOSED THREE-PART RATES CONSISTENT WITH THE RATEMAKING PRINCIPLE OF EQUITY?

A. Yes. Each customer imposes costs on the system, some of which are fixed and the rest of which are demand-driven and energy-driven. Under purely volumetric tariffs, customers with low load factors do not pay their fair share of the cost of maintaining, upgrading, and expanding the utility's generation, transmission and distribution system. Instead, customers with higher load factors cover the deficit and pay more than their fair share. Each of TEP's proposed three-part rates make progress on matching demand, fixed, and variable costs with demand, fixed, and variable charges. By doing so, TEP's proposals will reduce this inequity so that all customers will more fairly share in the costs associated with the generation of electricity, its delivery through utility's transmission and distribution system, and customer service.

Q. ARE TEP'S PROPOSED THREE-PART RATES CONSISTENT WITH THE RATEMAKING PRINCIPLE OF ECONOMIC EFFICIENCY?

A. Yes. As I discussed previously, the cost-based price signals in the three-part rates proposed by TEP provide customers with the financial incentive to make investments in technologies or otherwise change their behavior in ways that are most beneficial to the system. Technologies and behaviors that reduce a customer's demand should ultimately lead to a more efficient use of the grid, reduced costs, and lower bills.

A careful reading of the text by Bonbright suggests that, when he discusses efficiency, he means economic efficiency in the broad sense of the term and not just energy efficiency. The attainment of economic efficiency requires that resources are used in the least wasteful way possible. If a product is being consumed by someone who values that product at less than it costs to produce, then that consumption is wasteful and society would be better off on aggregate redeploying those resources elsewhere. In a decentralized market economy, prices are used to guide efficient resource use. Thus if a good is priced correctly, consumers who value it at less than its cost will not purchase it and an efficient outcome is achieved. In discussions about electricity consumption, the conversation often focuses on just one dimension of economic efficiency – energy conservation, which entails reducing the amount of electricity consumed. However there are other dimensions, where electricity consumption may be very inefficient, such as in demand. If capacity is essentially given away for free, then customers, who may place a very low value on capacity, will consume it, even if its cost to society (ultimately them and other customers) is very high.

Q. ARE TEP'S PROPOSED THREE-PART RATES CONSISTENT WITH THE RATEMAKING PRINCIPLE OF CUSTOMER SATISFACTION?

A. Yes. TEP is proposing to increase the diversity of its rate options for residential customers. Having a meaningful choice of cost-based pricing products is a benefit to customers. The three-part rates will be the standard rate offering for new DG PV customers. Those customers, too, will effectively opt-in to the new rate offering by making the choice to invest in a rooftop solar system.

Q. ARE TEP'S PROPOSED THREE-PART RATES CONSISTENT WITH THE RATEMAKING PRINCIPLE OF BILL STABILITY?

A. Rate design modifications are revenue neutral exercises. As a result, for the residential class as a whole, TEP's rate design proposal will not change the average bill. That would also be true for customers whose load profile is similar to that of the class average. Customers whose load factors are higher than the class average will experience lower bills on the voluntary three-part rate. Customers whose load factor is worse than the class average, because they have been subsidized for years by the customers whose load factor was higher than the class average, would experience higher bills if they enroll, since the change in rates will remove that subsidy. However, they will have an opportunity to lower their bills by reducing their demand. And that would also be true for customers who are automatically seeing lower bills. They will have an opportunity to further lower their bills by reducing their demand.

Q. ARE TEP'S PROPOSED THREE-PART RATES CONSISTENT WITH THE RATEMAKING PRINCIPLE OF REVENUE ADEQUACY AND STABILITY?

A. Yes. The introduction of a three-part rate will not change the utility's revenues. A properly designed three-part rate will be revenue neutral and is designed to collect the same revenue as the otherwise applicable two-part rates. The main reason for moving to three-part rates is the ability to more accurately recover costs from those customers who are imposing costs on the system, and to provide customers with an incentive to consume electricity in a more efficient manner.

While Professor Bonbright says that rates should be stable and predictable, he does not say that rate structures should remain frozen in time. In the U.S., there is an ineluctable movement towards cost-reflective rates brought about by the rollout of advanced metering and by the increased availability and customer adoption of a wide range of digital end-use technologies such as smart appliances, smart thermostats, home energy management systems, battery storage systems, electric vehicles and rooftop solar panels. TEP's three-part rate proposal is designed to provide stability in this new environment.

V. CONCLUSION

Q. WHAT ARE YOUR CONCLUSIONS ABOUT TEP'S THREE-PART RATE DESIGN PROPOSALS?

A. The two-part rate that is presently employed throughout the electric utility industry must give way to three-part rates. Not only are two-part rates ineffective at providing proper pricing signals, they do not facilitate the integration of distributed energy resources with the grid, nor do they stimulate the deployment of other innovative technologies such as customer-sited battery storage and plug-in electric vehicles.

TEP proposes to begin replacing its legacy two-part rate with three-part rates that are reasonable, cost-based, efficient, and equitable. In sum, they are consistent with well-established principles of rate design. In addition, TEP's proposed three-part rates better align costs with prices. In so doing, the proposed rates will provide a more accurate price signal to customers, promote the efficient use of energy around-the-clock, and encourage the development of new, demand-reducing technologies. I recommend that going forward, TEP should eventually make the demand charge a feature of the rate for all of its residential customers.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes, it does

Attachment AJF-1DR

Statement of Qualifications

Dr. Ahmad Faruqui is an economist with 40 years of academic, consulting and research experience in the efficient use of energy. He has assisted clients in the conceptualization, design, analysis, and evaluation of a wide range of programs related to advanced metering infrastructure, conservation voltage reduction, combined heat and power, demand charges, distributed energy resources, dynamic pricing, demand response, energy efficiency and newly emerging technologies, such as plug-in electric vehicles, rooftop solar, and distributed generation. He has provided regulatory support and testimony in proceedings related to these issues in 34 states, the District of Columbia and Canada.

Two of Dr. Faruqui's dynamic experiments have won professional awards, and he was named one of the world's Top 100 experts on the smart grid by Greentech Media.

He has consulted with more than 135 energy organizations around the globe and testified or appeared before a dozen state and provincial commissions and legislative bodies in the United States and Canada. He has also advised the Alberta Utilities Commission, the Edison Electric Institute, the Electric Power Research Institute, FERC, the Institute for Electric Efficiency, the Ontario Energy Board, the Saudi Electricity and Co-Generation Regulatory Authority, and the World Bank. His research on the energy behavior of consumers has been cited in Business Week, The Economist, Forbes, National Geographic, The New York Times, Fortune, the San Francisco Chronicle, the San Jose Mercury News, the Wall Street Journal, The Times (London) and USA Today. He has appeared on Fox Business News, National Public Radio and Voice of America.

Dr. Faruqui is the author, co-author or co-editor of four books and more than 150 articles, papers, and reports on efficient energy use. He has published in peer-reviewed journals such as Energy Economics, Energy Journal, Energy Efficiency, and the Journal of Regulatory Economics and trade journals such as The Electricity Journal and the Public Utilities Fortnightly. He has taught economics at San Jose State University, the University of California at Davis and the University of Karachi. He holds a an M.A. in agricultural economics and a Ph. D. in economics from The University of California at Davis, where he was a Regents Fellow, and B.A. and M.A. degrees in economics from The University of Karachi, where he was awarded the Rashid Minhas Gold Medal in economics and the Government of Pakistan Overseas Scholarship.

AREAS OF EXPERTISE

- *Innovative pricing.* He has identified, designed and analyzed the efficiency and equity benefits of introducing innovative pricing designs such as three-part rates, including fixed monthly charges, demand charges and time-varying energy charges; dynamic pricing rates, including critical peak pricing, variable peak pricing and real-time pricing; time-of-use pricing; and inclining block rates.
- *Rate design.* He has helped design forward-looking programs and services that exploit recent advances in rate design and digital technologies in order to lower customer bills and improve utility earnings while lowering the carbon footprint and preserving system reliability.
- *Cost-benefit analysis of advanced metering infrastructure.* He has assessed the feasibility of introducing smart meters and other devices, such as programmable communicating thermostats that promote demand response, into the energy marketplace, in addition to new appliances, buildings, and industrial processes that improve energy efficiency.
- *Demand forecasting and weather normalization.* He has pioneered the use of a wide variety of models for forecasting product demand in the near-, medium-, and long-term, using econometric, time series, and engineering methods. These models have been used to bid into energy procurement auctions, plan capacity additions, design customer-side programs, and weather normalize sales.
- *Customer choice.* He has developed methods for surveying customers in order to elicit their preferences for alternative energy products and alternative energy suppliers. These methods have been used to predict the market size of these products and to estimate the market share of specific suppliers.
- *Hedging, risk management, and market design.* He has helped design a wide range of financial products that help customers and utilities cope with the unique opportunities and challenges posed by a competitive market for electricity. He conducted a widely-cited market simulation to show that real-time pricing of electricity could have saved Californians millions of dollars during the Energy Crisis by lowering peak demands and prices in the wholesale market.

- *Competitive business strategy.* He has helped clients develop and implement competitive marketing strategies by drawing on his knowledge of the energy needs of end-use customers, their values and decision-making practices, and their competitive options. He has helped companies reshape and transform their marketing organization and reposition themselves for a competitive marketplace. He has also helped government-owned entities in the developing world prepare for privatization by benchmarking their planning, retailing, and distribution processes against industry best practices, and suggesting improvements by specifying quantitative metrics and follow-up procedures.
- *Design and evaluation of marketing programs.* He has helped generate ideas for new products and services, identified successful design characteristics through customer surveys and focus groups, and test marketed new concepts through pilots and experiments.
- *Expert witness.* He has testified or appeared before state commissions in Arizona, Arkansas, California, Colorado, Connecticut, Delaware, the District of Columbia, Illinois, Indiana, Iowa, Kansas, Michigan, Maryland, Minnesota, Nevada, New Mexico, Ohio, Oklahoma, Ontario (Canada), Pennsylvania and Texas. He has assisted clients in submitting testimony in Georgia. He has presented to the California Energy Commission, the California Senate, the Congressional Office of Technology Assessment, the Kentucky Commission, the Minnesota Department of Commerce, the Minnesota Senate, the Missouri Public Service Commission, and the Electricity Pricing Collaborative in the state of Washington. In addition, he has led a variety of professional seminars and workshops on public utility economics around the world and taught economics at the university level.

EXPERIENCE

Innovative Pricing

- **Report examining the costs and benefits of dynamic pricing in the Australian energy market.** For the Australian Energy Market Commission (AEMC), developed a report that reviews the various forms of dynamic pricing, such as time-of-use pricing, critical peak pricing, peak time rebates, and real time pricing, for a variety of performance metrics including economic efficiency, equity, bill risk, revenue risk, and risk to vulnerable customers. It also discusses ways in which dynamic pricing can be rolled out in Australia to raise load factors and lower average energy costs for all consumers without harming vulnerable consumers, such as those with low incomes or medical conditions requiring the use of electricity.

- **Whitepaper on emerging issues in innovative pricing.** For the Regulatory Assistance Project (RAP), developed a whitepaper on emerging issues and best practices in innovative rate design and deployment. The paper includes an overview of AMI-enabled electricity pricing options, recommendations for designing the rates and conducting experimental pilots, an overview of recent pilots, full-deployment case studies, and a blueprint for rolling out innovative rate designs. The paper's audience is international regulators in regions that are exploring the potential benefits of smart metering and innovative pricing.

- **Assessing the full benefits of real-time pricing.** For two large Midwestern utilities, assessed and, where possible, quantified the potential benefits of the existing residential real-time pricing (RTP) rate offering. The analysis included not only "conventional" benefits such as avoided resource costs, but under the direction of the state regulator was expanded to include harder-to-quantify benefits such as improvements to national security and customer service.

- **Pricing and Technology Pilot Design and Impact Evaluation for Connecticut Light & Power (CL&P).** Designed the Plan-It Wise Energy pilot for all classes of customers and subsequently evaluated the Plan-It Wise Energy program (PWEP) in the summer of 2009. PWEP tested the impacts of CPP, PTR, and time of use (TOU) rates on the consumption behaviors of residential and small commercial and industrial customers.

- **Dynamic Pricing Pilot Design and Impact Evaluation: Baltimore Gas & Electric.** Designed and evaluated the Smart Energy Pricing (SEP) pilot, which ran for four years from 2008 to 2011. The pilot tested a variety of rate designs including critical peak pricing and peak time rebates on residential customer consumption patterns. In addition, the pilot tested the impacts of smart thermostats and the Energy Orb.

- **Impact Evaluation of a Residential Dynamic Pricing Experiment: Consumers Energy (Michigan).** Designed the pilot and carried out an impact evaluation with the purpose of measuring the impact of critical peak pricing (CPP) and peak time rebates (PTR) on residential customer consumption patterns. The pilot also tested the influence of switches that remotely adjust the duty cycle of central air conditioners.

- **Impact Simulation of Ameren Illinois Utilities' Power Smart Pricing Program.** Simulated the potential demand response of residential customers enrolled to real-time prices. Results of this simulation were presented to the Midwest ISO's Supply Adequacy Working Group (SAWG) to explore alternative ways of introducing price responsive demand in the region.

- **The Case for Dynamic Pricing: Demand Response Research Center.** Led a project involving the California Public Utilities Commission, the California Energy Commission, the state's three investor-owned utilities, and other stakeholders in the rate design process. Identified key issues and barriers associated with the development of time-based rates. Revisited the fundamental objectives of rate design, including efficiency and equity, with a special emphasis on meeting the state's strongly-articulated needs for demand response and energy efficiency. Developed a score-card for evaluating competing rate designs and applied it to a set of illustrative rates that were created for four customer classes using actual utility data. The work was reviewed by a national peer-review panel.

- **Developed a Customer Price Response Model: Consolidated Edison.** Specified, estimated, tested, and validated a large-scale model that analyzes the response of some 2,000 large commercial customers to rising steam prices. The model includes a module for analyzing conservation behavior, another module for forecasting fuel switching behavior, and a module for forecasting sales and peak demand

- **Design and Impact Evaluation of the Statewide Pricing Pilot: Three California Utilities.** Working with a consortium of California's three investor-owned utilities to design a statewide pricing pilot to test the efficacy of dynamic pricing options for mass-market customers. The pilot was designed using scientific principles of experimental design and measured changes in usage induced by dynamic pricing for over 2,500 residential and small commercial and industrial customers. The impact evaluation was carried out using state-of-the-art econometric models.

Information from the pilot was used by all three utilities in their business cases for advanced metering infrastructure (AMI). The project was conducted through a public process involving the state's two regulatory commissions, the power agency, and several other parties.

- **Economics of Dynamic Pricing: Two California Utilities.** Reviewed a wide range of dynamic pricing options for mass-market customers. Conducted an initial cost-effectiveness analysis and updated the analysis with new estimates of avoided costs and results from a survey of customers that yielded estimates of likely participation rates.

- **Economics of Time-of-Use Pricing: A Pacific Northwest Utility.** This utility ran the nation's largest time-of-use pricing pilot program. Assessed the cost-effectiveness of alternative pricing options from a variety of different perspectives. Options included a standard three-part time-of-use rate and a quasi-real time variant where the prices vary by day. Worked with the client in developing a regulatory strategy. Worked later with a collaborative to analyze the program's economics under a variety of scenarios of the market environment.

- **Economics of Dynamic Pricing Options for Mass Market Customers – Client: A Multi-State Utility.** Identified a variety of pricing options suited to meet the needs of mass-market customers, and assessed their cost-effectiveness. Options included standard three-part time-of-use rates, critical peak pricing, and extreme-day pricing. Developed plans for implementing a pilot program to obtain primary data on customer acceptance and load shifting potential. Worked with the client in developing a regulatory strategy.

- **Real-Time Pricing in California – Client: California Energy Commission.** Surveyed the national experience with real-time pricing of electricity, directed at large power customers. Identified lessons learned and reviewed the reasons why California was unable to implement real-time pricing. Catalogued the barriers to implementing real-time pricing in California, and developed a program of research for mitigating the impacts of these barriers.

- **Market-Based Pricing of Electricity – Client: A Large Southern Utility.** Reviewed pricing methodologies in a variety of competitive industries including airlines, beverages, and automobiles. Recommended a path that could be used to transition from a regulated utility environment to an open market environment featuring customer choice in both wholesale and retail markets. Held a series of seminars for senior management and their staffs on the new methodologies.

- **Tools for Electricity Pricing – Client: Consortium of Several U.S. and Foreign Utilities.** Developed Product Mix, a software package that uses modern finance theory and econometrics to establish a profit-maximizing menu of pricing products. The products range from the traditional fixed-price product to time-of-use prices to hourly real-time prices, and also include products that can hedge customers' risks based on financial derivatives. Outputs include market share, gross revenues, and profits by product and provider. The calculations are performed using probabilistic simulation, and results are provided as means and standard deviations. Additional results include delta and gamma parameters that can be used for corporate risk management. The software relies on a database of customer load response to various pricing options called StatsBank. This database was created by metering the hourly loads of about one thousand commercial and industrial customers in the United States and the United Kingdom.
- **Risk-Based Pricing – Client: Midwestern Utility.** Developed and tested new pricing products for this utility that allowed it to offer risk management services to its customers. One of the products dealt with weather risk; another one dealt with risk that real-time prices might peak on a day when the customer does not find it economically viable to cut back operations.

Demand Response

- **National Action Plan for Demand Response: Federal Energy Regulatory Commission.** Led a consulting team developing a national action plan for demand response (DR). The national action plan outlined the steps that need to be taken in order to maximize the amount of cost-effective DR that can be implemented. The final document was filed with U.S. Congress in June 2010.
- **National Assessment of Demand Response Potential: Federal Energy Regulatory Commission.** Led a team of consultants to assess the economic and achievable potential for demand response programs on a state-by-state basis. The assessment was filed with the U.S. Congress in 2009, as required by the Energy Independence and Security Act of 2007.

- **Evaluation of the Demand Response Benefits of Advanced Metering Infrastructure: Mid-Atlantic Utility.** Conducted a comprehensive assessment of the benefits of advanced metering infrastructure (AMI) by developing dynamic pricing rates that are enabled by AMI. The analysis focused on customers in the residential class and commercial and industrial customers under 600 kW load.
- **Estimation of Demand Response Impacts: Major California Utility.** Worked with the staff of this electric utility in designing dynamic pricing options for residential and small commercial and industrial customers. These options were designed to promote demand response during critical peak days. The analysis supported the utility's advanced metering infrastructure (AMI) filing with the California Public Utilities Commission. Subsequently, the commission unanimously approved a $1.7 billion plan for rolling out nine million electric and gas meters based in part on this project work.

Smart Grid Strategy

- **Development of a smart grid investment roadmap for Vietnamese utilities.** For the five Vietnamese power corporations, developed a roadmap to guide future smart grid investment decisions. The report identified and described the various smart grid investment options, established objectives for smart grid deployment, presented a multi-phase approach to deploying the smart grid, and provided preliminary recommendations regarding the best investment opportunities. Also presented relevant case studies and an assessment of the current state of the Vietnamese power grid. The project involved in-country meetings as well as a stakeholder workshop that was conducted by Brattle staff.
- **Cost-Benefit Analysis of the Smart Grid: Rocky Mountain Utility.** Reviewed the leading studies on the economics of the smart grid and used the findings to assess the likely cost-effectiveness of deploying the smart grid in one geographical location.
- **Modeling benefits of smart grid deployment strategies.** Developed a model for assessing benefits of smart grid deployment strategies over a long-term (e.g., 20-year) forecast horizon. The model, called iGrid, is used to evaluate seven distinct smart grid programs and technologies (e.g., dynamic pricing, energy storage,

PHEVs) against seven key metrics of value (e.g., avoided resource costs, improved reliability).

- **Smart grid strategy in Canada.** The Alberta Utilities Commission (AUC) was charged with responding to a Smart Grid Inquiry issued by the provincial government. Advised the AUC on the smart grid, and what impacts it might have in Alberta.
- **Smart grid deployment analysis for collaborative of utilities.** Adapted the iGrid modeling tool to meet the needs of a collaborative of utilities in the southern U.S. In addition to quantifying the benefits of smart grid programs and technologies (e.g., advanced metering infrastructure deployment and direct load control), the model was used to estimate the costs of installing and implementing each of the smart grid programs and technologies.
- **Development of a smart grid cost-benefit analysis framework.** For the Electric Power Research Institute (EPRI) and the U.S. DOE, contributed to the development of an approach for assessing the costs and benefits of the DOE's smart grid demonstration programs.
- **Analysis of the benefits of increased access to energy consumption information.** For a large technology firm, assessed market opportunities for providing customers with increased access to real time information regarding their energy consumption patterns. The analysis includes an assessment of deployments of information display technologies and analysis of the potential benefits that are created by deploying these technologies.
- **Developing a plan for integrated smart grid systems.** For a large California utility, helped to develop applications for funding for a project to demonstrate how an integrated smart grid system (including customer-facing technologies) would operate and provide benefits.

Demand Forecasting

- **Comprehensive Review of Load Forecasting Methodology: PJM Interconnection.** Conducted a comprehensive review of models for forecasting peak demand and re-estimated new models to validate recommendations. Individual models were developed for 18 transmission zones as well as a model for the RTO system.

- **Analyzed Downward Trend: Western Utility.** We conducted a strategic review of why sales had been lower than forecast in a year when economic activity had been brisk. We developed a forecasting model for identifying what had caused the drop in sales and its results were used in an executive presentation to the utility's board of directors. We also developed a time series model for more accurately forecasting sales in the near term and this model is now being used for revenue forecasting and budgetary planning.
- **Analyzed Why Models are Under-Forecasting: Southwestern Utility.** Reviewed the entire suite of load forecasting models, including models for forecasting aggregate system peak demand, electricity consumption per customer by sector and the number of customers by sector. We ran a variety of forecasting experiments to assess both the ex-ante and ex-post accuracy of the models and made several recommendations to senior management.
- **U.S. Demand Forecast: Edison Electric Institute.** For the U.S. as a whole, we developed a base case forecast and several alternative case forecasts of electric energy consumption by end use and sector. We subsequently developed forecasts that were based on EPRI's system of end-use forecasting models. The project was done in close coordination with several utilities and some of the results were published in book form.
- **Developed Models for Forecasting Hourly Loads: Merchant Generation and Trading Company.** Using primary data on customer loads, weather conditions, and economic activity, developed models for forecasting hourly loads for residential, commercial, and industrial customers for three utilities in a Midwestern state. The information was used to develop bids into an auction for supplying basic generation services.
- **Gas Demand Forecasting System – Client: A Leading Gas Marketing and Trading Company, Texas.** Developed a system for gas nominations for a leading gas marketing company that operated in 23 local distribution company service areas. The system made week-ahead and month-ahead forecasts using advanced forecasting methods. Its objective was to improve the marketing company's profitability by minimizing penalties associated with forecasting errors.

Demand Side Management

- **The Economics of Biofuels.** For a western utility that is facing stringent renewable portfolio standards and that is heavily dependent on imported fossil fuels, carried out a systematic assessment of the technical and economic ability of biofuels to replace fossil fuels.

- **Assessment of Demand-Side Management and Rate Design Options: Large Middle Eastern Electric Utility.** Prepared an assessment of demand-side management and rate design options for the four operating areas and six market segments. Quantified the potential gains in economic efficiency that would result from such options and identified high priority programs for pilot testing and implementation. Held workshops and seminars for senior management, managers, and staff to explain the methodology, data, results, and policy implications.

- **Likely Future Impact of Demand-Side Programs on Carbon Emissions – Client: The Keystone Center.** As part of the Keystone Dialogue on Climate Change, developed scenarios of future demand-side program impacts, and assessed the impact of these programs on carbon emissions. The analysis was carried out at the national level for the U.S. economy, and involved a bottom-up approach involving many different types of programs including dynamic pricing, energy efficiency, and traditional load management.

- **Sustaining Energy Efficiency Services in a Restructured Market – Client: Southern California Edison.** Helped in the development of a regulatory strategy for implementing energy efficiency strategies in a restructured marketplace. Identified the various players that are likely to operate in a competitive market, such as third-party energy service companies (ESCOS) and utility affiliates. Assessed their objectives, strengths, and weaknesses and recommended a strategy for the client's adoption. This strategy allowed the client to participate in the new market place, contribute to public policy objectives, and not lose market share to new entrants. This strategy has been embraced by a coalition of several organizations involved in the California PUC's working group on public purpose programs.

- **Organizational Assessments of Capability for Energy Efficiency – Client: U.S. Agency for International Development, Cairo, Egypt.** Conducted in-depth interviews with senior executives of several energy organizations, including utilities, government agencies, and ministries to determine their goals and capabilities for implementing programs to improve energy end-use efficiency in Egypt. The interviews probed the likely future role of these organizations in a privatized energy market, and were designed to help develop U.S. AID's future funding agenda.

- **Enhancing Profitability Through Energy Efficiency Services – Client: Jamaica Public Service Company.** Developed a plan for enhancing utility profitability by providing financial incentives to the client utility, and presented it for review and discussion to the utility's senior management and Jamaica's new Office of Utility Regulation. Developed regulatory procedures and legislative language to support the implementation of the plan. Conducted training sessions for the staff of the utility and the regulatory body.

Advanced Technology Assessment

- **Competitive Energy and Environmental Technologies – Clients: Consortium of clients, led by Southern California Edison, Included the Los Angeles Department of Water and Power and the California Energy Commission.** Developed a new approach to segmenting the market for electrotechnologies, relying on factors such as type of industry, type of process and end use application, and size of product. Developed a user-friendly system for assessing the competitiveness of a wide range of electric and gas-fired technologies in more than 100 four-digit SIC code manufacturing industries and 20 commercial businesses. The system includes a database on more than 200 end-use technologies, and a model of customer decision making.

- **Market Infrastructure of Energy Efficient Technologies – Client: EPRI.** Reviewed the market infrastructure of five key end-use technologies, and identified ways in which the infrastructure could be improved to increase the penetration of these technologies. Data was obtained through telephone interviews with equipment manufacturers, engineering firms, contractors, and end-use customers.

TESTIMONY

Arizona

Testimony before the Arizona Corporation Commission on behalf of Arizona Public Service Company, in the matter of the Application for UNS Electric, Inc. for the Establishment of Just and Reasonable Rates and Charges Designed to Realize a Reasonable Rate of Return on the Fair Value of the Properties of UNS Electric, Inc. Devoted to the its Operations Throughout the State of Arizona, and for Related Approvals, Docket No. E-04204A-15-0142, December 9, 2015.

California

Rebuttal Testimony before the Public Utilities Commission of the State of California, Pacific Gas and Electric Company Joint Utilities on Demand Elasticity and Conservation Impacts of Investor-Owned Utility Proposals, in the Matter of Rulemaking 12-06-013, October 17, 2014.

Testimony before the Public Utilities Commission of the State of California on behalf of Pacific Gas and Electric Company on rate relief, Docket No. A.10-03-014, summer 2010.

Testimony before the Public Utilities Commission of the State of California, on behalf of Southern California Edison, Edison SmartConnect™ Deployment Funding and Cost Recovery, exhibit SCE-4, July 31, 2007.

Testimony on behalf of the Pacific Gas & Electric Company, in its application for Automated Metering Infrastructure with the California Public Utilities Commission. Docket No. 05-06-028, 2006.

Colorado

Rebuttal Testimony before the Public Utilities Commission of the State of Colorado in the Matter of Advice Letter No. 1535 by Public Service Company of Colorado to Revise its Colorado PUC No.7 Electric Tariff to Reflect Revised Rates and Rate Schedules to be Effective on June 5, 2009. Docket No. 09al-299e, November 25, 2009.

Testimony before the Public Utilities Commission of the State of Colorado, on behalf of Public Service Company of Colorado, on the tariff sheets filed by Public Service Company of Colorado with advice letter No. 1535 – Electric. Docket No. 09S-__E, May 1, 2009.

Connecticut

Testimony before the Department of Public Utility Control, on behalf of the Connecticut Light and Power Company, in its application to implement Time-of-Use , Interruptible Load Response, and Seasonal Rates- Submittal of Metering and Rate Pilot Results- Compliance Order No. 4, Docket no. 05-10-03RE01, 2007.

District of Columbia

Testimony before the Public Service Commission of the District of Columbia on behalf of Potomac Electric Power Company in the matter of the Application of Potomac Electric Power Company for Authorization to Establish a Demand Side Management Surcharge and an Advance Metering Infrastructure Surcharge and to Establish a DSM Collaborative and an AMI Advisory Group, case no. 1056, May 2009.

Illinois

Testimony on rehearing before the Illinois Commerce Commission on behalf of Ameren Illinois Company, on the Smart Grid Advanced Metering Infrastructure Deployment Plan, Docket No. 12-0244, June 28, 2012.

Testimony before the State of Illinois – Illinois Commerce Commission on behalf of Commonwealth Edison Company regarding the evaluation of experimental residential real-time pricing program, 11-0546, April 2012.

Rebuttal Testimony before the Illinois Commerce Commission on behalf of Commonwealth Edison, on the Advanced Metering Infrastructure Pilot Program, ICC Docket No. 06-0617, October 30, 2006.

Indiana

Testimony before the State of Indiana, Indiana Utility Regulatory Commission, on behalf of Vectren South, on the smart grid. Cause no. 43810, 2009.

Kansas

Testimony before the State Corporation Commission of the State of Kansas, on behalf of Westar Energy, in the matter of the Application of Westar Energy, Inc. and Kansas Gas and Electric

Company to Make Certain Changes in Their Charges for Electric Service, Docket No. 15-WSEE-115-RTS, March 2, 2015.

Maryland

Testimony before the Maryland Public Service Commission, on behalf of Potomac Electric Power Company in the matter of the application of Potomac Electric Power Company for adjustments to its retail rates for the distribution of electric energy, April 19, 2016.

Rebuttal testimony, before the Maryland Public Service Commission, on behalf of Baltimore Gas and Electric Company in the matter of the application of Baltimore Gas and Electric Company for adjustments to its electric and gas base rates, Case No. 9406, March 4, 2016.

Testimony before the Public Service Commission of Maryland, on behalf of Potomac Electric Power Company and Delmarva Power and Light Company, on the deployment of Advanced Meter Infrastructure, Case no. 9207, September 2009.

Testimony before the Maryland Public Service Commission, on behalf of Baltimore Gas and Electric Company, on the findings of BGE's Smart Energy Pricing ("SEP") Pilot program. Case No. 9208, July 10, 2009.

Minnesota

Rebuttal Testimony before the Minnesota Public Utilities Commission State of Minnesota on behalf of Northern States Power Company, doing business as Xcel Energy, in the matter of the Application of Northern States Power Company for Authority to Increase Rates for Electric Service in Minnesota, Docket No. E002/GR-12-961, March 25, 2013.

Testimony before the Minnesota Public Utilities Commission State of Minnesota on behalf of Northern States Power Company, doing business as Xcel Energy, in the matter of the Application of Northern States Power Company for Authority to Increase Rates for Electric Service in Minnesota, Docket No. E002/GR-12-961, November 2, 2012.

Nevada

Rebuttal Testimony before the Public Utilities Commission of Nevada on behalf of Nevada Power Company and Sierra Pacific Power Company d/b/a NV Energy, in the matter of net metering and distributed generation cost of service and tariff design, Docket Nos. 15-07041 and 15-07042, November 3, 2015.

Testimony before the Public Utilities Commission of Nevada on behalf of Nevada Power Company d/b/a NV Energy, in the matter of the application for approval of a cost of service study and net metering tariffs, Docket No. 15-07, July 31, 2015.

New Mexico

Testimony before the New Mexico Regulation Commission on behalf of Public Service Company of New Mexico in the matter of the Application of Public Service Company of New Mexico for Revision of its Retail Electric Rates Pursuant to Advice Notice No. 507, Case No. 14-00332-UT, December 11, 2014.

Pennsylvania

Testimony before the Pennsylvania Public Utility Commission, on behalf of PECO on the Methodology Used to Derive Dynamic Pricing Rate Designs, Case No. M-2009-2123944, October 28, 2010.

Oklahoma

Rebuttal Testimony before the Corporation Commission of Oklahoma on behalf of Oklahoma Gas and Electric Company in the matter of the Oklahoma Gas and Electric Company for an order of the Commission authorizing applicant to modify its rates, charges and tariffs for retail electric service in Oklahoma, Cause No. PUD 201500273, April 11, 2016.

Direct Testimony before the Corporation Commission of Oklahoma on behalf of Oklahoma Gas and Electric Company in the matter of the Oklahoma Gas and Electric Company for an order of the Commission authorizing applicant to modify its rates, charges and tariffs for retail electric service in Oklahoma, Cause No. PUD 201500273, December 3, 2015.

Responsive Testimony before the Corporation Commission of Oklahoma on behalf of Oklahoma Gas and Electric Company in the matter of the Application of Brandy L. Wreath, Director of the Public Utility Division, for Determination of the Calculation of Lost Net Revenues and Shared Savings Pursuant to the Demand Program Rider of Oklahoma Gas and Electric Company, Cause No. PUD 201500153, May 13, 2015.

REGULATORY APPEARANCES

Arkansas

Presented before the Arkansas Public Service Commission, "The Emergence of Dynamic Pricing" at the workshop on the Smart Grid, Demand Response, and Automated Metering Infrastructure, Little Rock, Arkansas, September 30, 2009.

Delaware

Presented before the Delaware Public Service Commission, "The Demand Response Impacts of PHI's Dynamic Pricing Program" Delaware, September 5, 2007.

Kansas

Presented before the State Corporation Commission of the State of Kansas, "The Impact of Dynamic Pricing on Westar Energy" at the Smart Grid and Energy Storage Roundtable, Topeka, Kansas, September 18, 2009.

Ohio

Presented before the Ohio Public Utilities Commission, "Dynamic Pricing for Residential and Small C&I Customers" at the Technical Workshop, Columbus, Ohio, March 28, 2012.

Texas

Presented before the Public Utility Commission of Texas, "Direct Load Control of Residential Air Conditioners in Texas," at the PUCT Open Meeting, Austin, Texas, October 25, 2012.

PUBLICATIONS

Presentations

1. "Time Variant Electricity Pricing: Theory and Implementation," Georgetown University's CSIS. A 90-minute panel session on time-variant pricing. Washington, DC, April 20, 2016. https://www.youtube.com/watch?v=0p6ZHaXszRQ

2. "Residential Demand Charges: An Overview," presented to EEI Rate Committee Meeting, Charlotte, NC, March 15, 2016.

3. "A Conversation About Standby Rates," presented to Standby Rate Working Group, Michigan Public Service Commission, Lansing, Michigan, January 20, 2016.

4. "Imaging the Utility of the Future," presented to Commonwealth Edison Company, January 12, 2016.

5. "The Movement Towards Deploying Demand Charges for Residential Customers," NARUC 127th Annual Meeting, Austin, Texas, November 8, 2015.

6. "Comments on the Straw Proposal on behalf of the California Water Association," presented at the CPUC Workshop on Balanced Rates Rulemaking (R.) 11-11-0008, San Francisco, October 13, 2015.

7. "A Global Perspective on Time-Varying Rates," presented at the Stanford Bits & Watts Program, August 12, 2015. http://www.brattle.com/system/publications/pdfs/000/005/183/original/A_global_perspective_on_time-varying_rates_Faruqui_061915.pdf?1436207012

8. "The Case for Introducing Demand Charges in Residential Tariffs," presented to the Harvard Electricity Policy Group 79th Plenary Session, Washington, D.C., June 25, 2015.

9. "A Global Perspective on Time-Varying Rates," presented to the CAMPUT Energy Regulation Course, Kingston, Ontario, June 23, 2015.

10. "The Global Movement Toward Cost-Reflective Tariffs," presented at the EUCI Residential Demand Charges Summit, Denver, Colorado, May 14, 2015.

11. "Currents of Change in the Design of Tariffs for Distribution Networks," presented at Energy Network Association: Energy Transformed, Sydney, Australia, May 7, 2015.

12. "Points of Inflection Loom Ahead for Demand Response and Distributed Generation," presented at the Comverge Utility Conference, St. Petersburg, Florida, April 10, 2015.

13. "Time-Variant Pricing (TVP) in New York," presented at the Time-Variant Pricing Forum, NYU School of Law, New York, New York, March 31, 2015. http://www.sallan.org/Sallan_In-the-Media/2015/04/rev_agenda_time_variant_p.php

14. "The Evolving Futures of Demand Response and Distributed Generation," presented to Eastern Interconnection States Planning Council, Newark, New Jersey, March 5, 2015.

15. "The Impact of Distributed Generation on Electric Sales," resented to Eastern Interconnection States Planning Council, Newark, New Jersey, March 5, 2015.

16. "The Five Forces Shaping the Future of Demand Response (DR)," presented at the Demand Response Virtual Summit 2015, February 19, 2015.

17. "The Impact of an Uncertain Economic Outlook on Electric Utilities," presented at the New Mexico Economic Outlook Conference 2015, January 15, 2015. http://www.bizjournals.com/albuquerque/news/2015/01/15/see-one-economists-view-on-why-electric-utilities.html

18. "The Re-emergence of Combined Heat and Power (CHP), presented at the NRRI Teleseminar, August 27, 2014.

19. "Moving Demand Response Back to the Demand Side," presented at the IEEE Power & Energy Society General Meeting, Harbor, Maryland, July 28, 2014.

20. "Price-Enabled Demand Response," presented to the Thai Energy Regulatory Commission, OERC, and Utilities Delegation, Boston, Massachusetts, July 16, 2014.

21. "Quantile Regression for Peak Demand Forecasting," with Charlie Gibbons, July 1, 2014.

22. "Strategies for Surviving Sub-One Percent Growth and the Emergence of the Energy Services Utility," presented at the 2014 UEC Summit, Coeur d'Alene, Idaho, June 24, 2014.

23. "The Emergence of the Energy Services Utility," presented at the North Carolina Electric Membership Corporation, June 5, 2014.

24. "Surviving Sub-One Percent Sales Growth," presented at the ACC Workshop, Phoenix, Arizona, March 20, 2014.

25. "The Customer-Side Benefits of Smart Meters," presented at the Smart Meter Symposium, Hong Kong, November 7, 2013.

26. "The Global Tao of the Smart Grid," presented at the 3rd Guangdong, Macau Power Industry Summit, Hong Kong, November 7, 2013.

27. "The Potential for Demand Response to Integrate Variable Energy Resources with the Grid," presented at the Joint CREPC/SPSC Meeting, San Diego, California, November 1, 2013.

28. "Policies for Energy Provider-Delivered Energy Efficiency in North America," with Jurgen Weiss, presented to The World Bank, October 17, 2013.

29. "Dynamic Pricing – The Bridge to a Smart Energy Future," presented at the World Smart Grid Forum, Berlin, Germany, September 25, 2013.

30. "Redefining California's Energy Future," presented at the Governor's Grid Conference, Palo Alto, California, September 10, 2013.

31. "Resolving the Crisis in Rate Design," presented at the EEI AltReg Webinar, August 2, 2013.

32. "Dynamic Pricing 2.0: The Grid-Integration of Renewables," presented at the IEEE PES GM 2013 Meetings, Vancouver, Canada, July, 23, 2013.

33. "The Clash of the Dynamic Pricing Titans: Faruqui v Toney – Part 1," Northwestern University's Kellogg Alumni Club. A two hour debate on the merits of dynamic pricing. San Francisco, CA, February 17, 2011. https://vimeo.com/20206833

Books

Electricity Pricing in Transition. Co-editor with Kelly Eakin. Kluwer Academic Publishing, 2002.

Pricing in Competitive Electricity Markets. Co-editor with Kelly Eakin. Kluwer Academic Publishing, 2000.

Customer Choice: Finding Value in Retail Electricity Markets. Co-editor with J. Robert Malko. Public Utilities Inc. Vienna. Virginia: 1999.

The Changing Structure of American Industry and Energy Use Patterns. Co-editor with John Broehl. Battelle Press, 1987.

Technical Reports

1. *Analysis of Ontario's Full Scale Roll-out of TOU Rates – Final Study,* with Neil Lessem, Sanem Sergici, Dean Mountain, Frank Denton, Byron Spencer, and Chris King, prepared for Independent Electric System Operator, February 2016. http://www.ieso.ca/Documents/reports/Final-Analysis-of-Ontarios-Full-Scale-Roll-Out-of-TOU-Rates.pdf

2. *Quantifying the Amount and Economic Impacts of Missing Energy Efficiency in PJM's Load Forecast,* with Sanem Sergici and Kathleen Spees, prepared for The Sustainable FERC Project, September 2014.

3. *Structure of Electricity Distribution Network Tariffs: Recovery of Residual Costs,* with Toby Brown, prepared for the Australian Energy Market Commission, August 2014.

4. *Impact Evaluation of Ontario's Time-of-Use Rates: First Year Analysis,* with Sanem Sergici, Neil Lessem, Dean Mountain, Frank Denton, Byron Spencer, and Chris King, prepared for Ontario Power Authority, November 2013.

5. *Time-Varying and Dynamic Rate Design*, with Ryan Hledik and Jennifer Palmer, prepared for RAP, July 2012. http://www.raponline.org/document/download/id/5131

6. *The Costs and Benefits of Smart Meters for Residential Customers*, with Adam Cooper, Doug Mitarotonda, Judith Schwartz, and Lisa Wood, prepared for Institute for Electric Efficiency, July 2011.
7. http://www.smartgridnews.com/artman/uploads/1/IEE_Benefits_of_Smart_Meters_Final.pdf

8. *Measurement and Verification Principles for Behavior-Based Efficiency Programs*, with Sanem Sergici, prepared for Opower, May 2011. http://opower.com/uploads/library/file/10/brattle_mv_principles.pdf

9. *Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects.* With R. Lee, S. Bossart, R. Hledik, C. Lamontagne, B. Renz, F. Small, D. Violette, and D. Walls. Pre-publication draft, prepared for the U. S. Department of Energy, Office of Electricity Delivery and Energy Reliability, the National Energy Technology Laboratory, and the Electric Power Research Institute. Oak Ridge, TN: Oak Ridge National Laboratory, November 28, 2009.

10. *Moving Toward Utility-Scale Deployment of Dynamic Pricing in Mass Markets.* With Sanem Sergici and Lisa Wood. Institute for Electric Efficiency, June 2009.

11. *Demand-Side Bidding in Wholesale Electricity Markets.* With Robert Earle. Australian Energy Market Commission, 2008. http://www.aemc.gov.au/electricity.php?r=20071025.174223

12. *Assessment of Achievable Potential for Energy Efficiency and Demand Response in the U.S. (2010-2030).* With Ingrid Rohmund, Greg Wikler, Omar Siddiqui, and Rick Tempchin. American Council for an Energy-Efficient Economy, 2008.

13. *Quantifying the Benefits of Dynamic Pricing in the Mass Market.* With Lisa Wood. Edison Electric Institute, January 2008.

14. California Energy Commission. *2007 Integrated Energy Policy Report,* CEC-100-2007-008-CMF.

15. *Applications of Dynamic Pricing in Developing and Emerging Economies.* Prepared for The World Bank, Washington, DC. May 2005.

16. *Preventing Electrical Shocks: What Ontario—And Other Provinces—Should Learn About Smart Metering.* With Stephen S. George. C. D. Howe Institute Commentary, No. 210, April 2005.

17. *Primer on Demand-Side Management.* Prepared for The World Bank, Washington, DC. March 21, 2005.

18. *Electricity Pricing: Lessons from the Front.* With Dan Violette. White Paper based on the May 2003 AESP/EPRI Pricing Conference, Chicago, Illinois, EPRI Technical Update 1002223, December 2003.

19. *Electric Technologies for Gas Compression.* Electric Power Research Institute, 1997.

20. *Electrotechnologies for Multifamily Housing.* With Omar Siddiqui. EPRI TR-106442, Volumes 1 and 2. Electric Power Research Institute, September 1996.

21. *Opportunities for Energy Efficiency in the Texas Industrial Sector.* Texas Sustainable Energy Development Council. With J. W. Zarnikau et al. June 1995.

22. *Principles and Practice of Demand-Side Management.* With John H. Chamberlin. EPRI TR-102556. Palo Alto: Electric Power Research Institute, August 1993.

23. *EPRI Urban Initiative: 1992 Workshop Proceedings (Part I).* The EPRI Community Initiative. With G.A. Wikler and R.H. Manson. TR-102394. Palo Alto: Electric Power Research Institute, May 1993.

24. *Practical Applications of Forecasting Under Uncertainty.* With K.P. Seiden and C.A. Sabo.TR-102394. Palo Alto: Electric Power Research Institute, December 1992.

25. *Improving the Marketing Infrastructure of Efficient Technologies:* A Case Study Approach. With S.S. Shaffer. EPRI TR- I 0 1 454. Palo Alto: Electric Power Research Institute, December 1992.

26. *Customer Response to Rate Options.* With J. H. Chamberlin, S.S. Shaffer, K.P. Seiden, and S.A. Blanc. CU-7131. Palo Alto: Electric Power Research Institute (EPRI), January 1991.

27. *Customer Response to Time of Use Rates: Topic Paper I*, with Dennis Aigner and Robert T. Howard, Electric Utility Rate Design Study, EPRI, 1981.

Articles and Chapters

1. "An Economist's Dilemma: To PV or Not to PV, That Is the Question," *Electricity Policy*, March 2016. http://www.electricitypolicy.com/Articles/an-economists-dilemma-to-pv-or-not-to-pv-that-is-the-question

2. "Response to King-Datta Re: Time-Varying Rates," *Public Utilities Fortnightly*, March 2016.

3. "Impact Measurement of Tariff Changes when Experimentation is not an Option – A case study of Ontario, Canada," with Sanem Sergici, Neil Lessem, and Dean Mountain, *Energy Economics*, 52, December 2015, pp. 39-48.

4. "Efficient Tariff Structures for Distribution Network Services," with Toby Brown and Lea Grausz, *Economic Analysis and Policy*, 48, December 2015, pp. 139-149.

5. "Impact Measurement of Tariff Changes when Experimentation is Not an Option – A Case Study of Ontario, Canada," *Energy Economics*, October 30, 2015.

6. "The Emergence of Organic Conservation," with Ryan Hledik and Wade Davis, The Electricity Journal, Volume 28, Issue 5, June 2015, pp. 48-58. http://www.sciencedirect.com/science/article/pii/S1040619015001074

7. "The Paradox of Inclining Block Rates," with Ryan Hledik and Wade Davis, *Public Utilities Fortnightly*, April 2015. http://www.fortnightly.com/fortnightly/2015/04/paradox-inclining-block-rates

8. "Making the Most of the No Load Growth Business Environment," with Dian Grueneich. *Distributed Generation and Its Implications for the Utility Industry*. Ed. Fereidoon P. Sioshansi. Academic Press, 2014. 303-320.

9. "*Arcturus*: An International Repository of Evidence on Dynamic Pricing," with Sanem Sergici. *Smart Grid Applications and Developments, Green Energy and Technology*. Ed. Daphne Mah, Ed. Peter Hills, Ed. Victor O. K. Li, Ed. Richard Balme. Springer, 2014. 59-74.

10. "Smart By Default," with Ryan Hledik and Neil Lessem, *Public Utilities Fortnightly*, August 2014. http://www.fortnightly.com/fortnightly/2014/08/smart-default?page=0%2C0&authkey=e5b59c3e26805e2c6b9e469cb9c1855a9b0f18c67bbe7d8d4ca08a8abd39c54d

11. "Quantile Regression for Peak Demand Forecasting," with Charlie Gibbons, SSRN, July 31, 2014. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2485657

12. "Study Ontario for TOU Lessons," *Intelligent Utility*, April 1, 2014. http://community.energycentral.com/community/energy-biz/study-ontario-time-use-tou-lessons

13. "Impact Measurement of Tariff Changes When Experimentation is Not an Option – a Case Study of Ontario, Canada," with Sanem Sergici, Neil Lessem, and Dean Mountain, SSRN, March 2014.

14. "Dynamic Pricing in a Moderate Climate: The Evidence from Connecticut," with Sanem Sergici and Lamine Akaba, *Energy Journal*, 35:1, pp. 137-160, January 2014.

15. "Will Energy Efficiency make a Difference," with Fereidoon P. Sioshansi and Gregory Wikler. *Energy Efficiency: Towards the end of demand growth.* Ed. Fereidoon P. Sioshansi. Academic Press, 2013. 3-50.

16. "Charting the DSM Sales Slump," with Eric Schultz, *Spark*, September 2013. http://spark.fortnightly.com/fortnightly/charting-dsm-sales-slump

17. "Arcturus: International Evidence on Dynamic Pricing," with Sanem Sergici, *The Electricity Journal*, 26:7, August/September 2013, pp. 55-65. http://www.sciencedirect.com/science/article/pii/S1040619013001656

18. "Dynamic Pricing of Electricity for Residential Customers: The Evidence from Michigan," with Sanem Sergici and Lamine Akaba, *Energy Efficiency*, 6:3, August 2013, pp. 571–584.

19. "Benchmarking your Rate Case," with Ryan Hledik, *Public Utility Fortnightly*, July 2013. http://www.fortnightly.com/fortnightly/2013/07/benchmarking-your-rate-case

20. "Surviving Sub-One-Percent Growth," *Electricity Policy*, June 2013. http://www.electricitypolicy.com/articles/5677-surviving-sub-one-percent-growth

21. "Demand Growth and the New Normal," with Eric Shultz, *Public Utility Fortnightly*, December 2012. http://www.fortnightly.com/fortnightly/2012/12/demand-growth-and-new-normal?page=0%2C1&authkey=4a6cf0a67411ee5e7c2aee5da4616b72fde10e3fbe215164cd4e5dbd8e9d0c98

22. "The Ethics of Dynamic Pricing." *Smart Grid: Integrating Renewable, Distributed & Efficient Energy*. Ed. Fereidoon P. Sioshansi. Academic Press, 2012. 61-83.

23. "The Discovery of Price Responsiveness – A Survey of Experiments Involving Dynamic Pricing of Electricity," with Jennifer Palmer, *Energy Delta Institute*, Vol.4, No. 1, April 2012. http://www.energydelta.org/mainmenu/edi-intelligence-2/our-services/quarterly-2/edi-quarterly-vol-4-issue-1

24. "Energy Efficiency and Demand Response in 2020 – A Survey of Expert Opinion," with Doug Mitarotonda, March 2012. http://ssrn.com/abstract=2029150

25. "Dynamic Pricing for Residential and Small C&I Customers," presented at the Ohio Public Utilities Commission Technical Workshop, March 28, 2012. http://www.brattle.com/_documents/UploadLibrary/Upload1026.pdf

26. "Green Ovations: Innovations in Green Technologies," with Pritesh Gandhi, *Electric Energy T&D Magazine*, January-February 2012. http://www.electricenergyonline.com/?page=show_article&mag=76&article=618

27. "Dynamic Pricing of Electricity and its Discontents" with Jennifer Palmer, *Regulation*, Volume 34, Number 3, Fall 2011, pp. 16-22. http://www.cato.org/pubs/regulation/regv34n3/regv34n3-5.pdf

28. "Smart Pricing, Smart Charging," with Ryan Hledik, Armando Levy, and Alan Madian, *Public Utility Fortnightly*, Volume 149, Number 10, October 2011. http://www.fortnightly.com/archive/puf_archive_1011.cfm

29. "The Energy Efficiency Imperative" with Ryan Hledik, *Middle East Economic Survey*, Vol LIV: No. 38, September 19, 2011.

30. "Are LDCs and customers ready for dynamic prices?" with Jürgen Weiss, *Fortnightly's Spark*, August 25, 2011. http://spark.fortnightly.com/sitepages/pid58.php?ltemplate=intro_archive&pageId=58&lcommtypeid=6&item_id=33

31. "Dynamic pricing of electricity in the mid-Atlantic region: econometric results from the Baltimore gas and electric company experiment," with Sanem Sergici, *Journal of Regulatory Economics*, 40:1, August 2011, pp. 82-109.

32. "Better Data, New Conclusions," with Lisa Wood, *Public Utilities Fortnightly*, March 2011, pp. 47-48. http://www.fortnightly.com/archive/puf_archive_0311.cfm

33. "Residential Dynamic Pricing and 'Energy Stamps,'" *Regulation*, Volume 33, No. 4, Winter 2010-2011, pp. 4-5. http://www.cato.org/pubs/regulation/regv33n4/v33n4.html

34. "Dynamic Pricing and Low-Income Customers: Correcting misconceptions about load-management programs," with Lisa Wood, *Public Utilities Fortnightly*, November 2010, pp. 60-64. http://www.fortnightly.com/archive/puf_archive_1110.cfm

35. "The Untold Story: A Survey of C&I Dynamic Pricing Pilot Studies" with Jennifer Palmer and Sanem Sergici, *Metering International*, ISSN: 1025-8248, Issue: 3, 2010, p.104.

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37. "Unlocking the €53 billion savings from smart meters in the EU: How increasing the adoption of dynamic tariffs could make or break the EU's smart grid investment," with Dan Harris and Ryan Hledik, *Energy Policy*, Volume 38, Issue 10, October 2010, pp. 6222-6231. http://www.sciencedirect.com/science/article/pii/S0301421510004738

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Attachment AJF-2DR

Summary of Residential Three-Part Rates

Summary of Residential Three-Part Tariffs

#	Utility	Utility Ownership	State	Residential Customers Served	Fixed charge ($/month)	Demand Charge ($/kW-month) Summer	Demand Charge ($/kW-month) Winter	Timing of demand measurement	Demand interval	Combined with Energy TOU?	Applicable Residential Customer Segment	Mandatory or Voluntary
[1]	Alabama Power	Investor Owned	AL	1,241,998	14.50	1.50	1.50	Any time	15 min	Yes	All	Voluntary
[2]	Alaska Electric Light and Power	Investor Owned	AK	13,968	11.49	6.72	11.11	Any time	Unknown	No	All	Voluntary
[3]	Arizona Public Service	Investor Owned	AZ	1,019,292	16.96	13.50	9.30	Peak Coincident	60 min	Yes	All	Voluntary
[4]	Black Hills Power	Investor Owned	SD	54,617	13.00	8.10	8.10	Any time	15 min	No	All	Voluntary
[5]	Black Hills Power	Investor Owned	WY	2,153	15.50	8.25	8.25	Any time	15 min	No	All	Voluntary
[6]	Butler Rural Electric Cooperative	Cooperative	KS	7,000	25.00	5.00	5.00	Any time	60 min	No	All	Mandatory
[7]	City of Fort Collins Utilities	Municipal	CO	60,464	5.37	2.50	2.50	Any time	Unknown	No	All	Voluntary
[8]	City of Kinston	Municipal	NC	9,776	14.95	9.35	9.35	Peak Coincident	15 min	No	All	Voluntary
[9]	City of Longmont	Municipal	CO	34,697	15.40	5.75	5.75	Any time	15 min	No	All	Voluntary
[10]	Dakota Electric Association	Cooperative	MN	94,924	12.00	14.70	11.10	Any time	15 min	No	All	Voluntary
[11]	Dominion	Investor Owned	NC	101,158	16.39	8.25	4.83	Peak Coincident	30 min	Yes	All	Voluntary
[12]	Dominion	Investor Owned	VA	2,105,500	12.00	5.68	3.95	Peak Coincident	30 min	Yes	All	Voluntary
[13]	Duke Energy Carolinas, LLC	Investor Owned	NC	1,608,151	13.38	7.77	3.88	Peak Coincident	30 min	Yes	All	Voluntary
[14]	Duke Energy Carolinas, LLC	Investor Owned	SC	460,178	9.93	8.15	4.00	Peak Coincident	30 min	Yes	All	Voluntary
[15]	Fort Morgan	Municipal	CO	5,273	6.13	10.22	10.22	Unknown	Unknown	No	All	Voluntary
[16]	Georgia Power	Investor Owned	GA	2,072,622	10.00	6.64	6.64	Any time	30 min	Yes	All	Voluntary
[17]	Mid-Carolina Electric Cooperative	Cooperative	SC	55,000	24.00	12.00	12.00	Any time	60 min	No	All	Mandatory
[18]	Midwest Energy Inc	Cooperative	KS	29,951	22.00	6.40	6.40	Any time	15 min	No	All	Voluntary
[19]	Otter Tail Power Company	Investor Owned	MN	47,699	16.00	6.08	5.11	Any time	60 min	No	All	Voluntary
[20]	Otter Tail Power Company	Investor Owned	ND	44,910	18.38	6.52	2.63	Any time	60 min	No	All	Voluntary
[21]	Otter Tail Power Company	Investor Owned	SD	8,648	13.00	7.05	5.93	Any time	60 min	No	All	Voluntary
[22]	Salt River Project	Political Subdivision	AZ	891,668	32.44 or 45.44	9.59 to 34.19	3.41 to 9.37	Peak Coincident	30 min	Yes	DG only	Mandatory
[23]	Swanton Village Electric Department	Municipal	VT	3,208	26.57	6.77	6.77	Any time	Unknown	No	All	Mandatory
[24]	Westar Energy	Investor Owned	KS	700,000	16.50	6.78	2.09	Any time	30 min	No	All	Voluntary
[25]	Xcel Energy (PSCo)	Investor Owned	CO	1,182,093	12.25	8.57	6.59	Any time	15 min	No	All	Voluntary

Sources: Utility tariffs as of April 2016, and "Form EIA-861 2013 data files, EIA_861_Retail_Sales_2013.xls" (for Utility ownership and Residential Customers Served columns).

Notes:

Peak periods are applicable from Monday through Friday excluding holidays. For some utilities, the monthly fixed charge has been calculated by multiplying a daily charge by 30.5.

[2]: Mandatory if customer consumes more than 5,000 kWh per month for three consecutive months or has a recorded peak demand of 20 KW for three consecutive months.

[3]: The monthly fixed charge is a daily basic service charge multiplied by 30.5 days.

[4]-[5]: Black Hills also offers an optional time-of-use rate that includes both energy and demand charges for customers owning demand controllers.

[12]: Demand charge is the sum of the distribution demand charge and the generation demand charge. The distribution demand charge is $1.612/kW and the generation demand charge is $4.070/kW for the summer and $2.334/kW for the winter.

[15]: The timing of demand measurement and the demand interval are not explicitly identified in the publicly available information we have reviewed.

[18]: The demand charge is based on the greater of the highest average 15 minute kW demand measured during the period for which the bill is rendered, and 80% of the average 15 minute maximum demand for the last three summer months.

[19]-[21]: Demand is measured as the maximum winter demand for the most recent 12 months. New customers have an assumed demand of 3 kW for their first year. Fixed charge for MN is customer charge per month plus facilities charge per month. Fixed charge for ND and SD is just customer charge per month.

[22]: Customers below 200 amps pay a fixed charge of $32.55 per month and customers above 200 amps pay $45.44 per month. Demand charges vary across three seasons: Winter, Summer (May, June, September, and October), and On-Peak Summer (July and August). The summer demand charges shown here apply for the On-Peak Summer period. The (on-peak) summer demand charge is $9.59 for up to 3kW of demand, 17.82 for the next 7kW, and 34.19 for over 10kW. The winter demand charge is $3.41 for up to 3kW, 5.46 for the next 7kW, and $9.37 over 10kW. The utility is experimentally offering the rate plan to a limited number of non-DG customers.

[23]: The demand charge is based on the greater of the measured demand for the current month and 85% of the highest recorded demand established during the preceding eleven months. The rate is mandatory for all residential customers with monthly consumption equal to or greater than 1,800 kWh, measured on a rolling 12 month average basis.

Attachment AJF-3D

Cross-Subsidy Illustration Model

Overview

This model presents a simplified, hypothetical example of cross-subsidization among an electric utility's customers due to mismatch between rate structures and cost structures.
Households are segmented by low, standard and high monthly energy usage.
Demand costs are considered separately from fixed costs.

Explanation of Inputs (See Cell Formulas for Further Detail)

- Revenue Requirement: the annual amount of revenue the utility is allowed to earn. Full recovery is assumed (i.e. total revenue = total costs). Fixed, variable, and demand rates are calculated based off of the revenue requirment.
- Households: the number of customers the utility serves.
- Average Household Usage: the average household's monthly usage (kWh).

- Average Household Max Demand: sets the amount of demand (kW) for the standard household group.
- Household distribution: determines the share of households in low and high-usage customer groups. A value of 1/3 (~.33) results in equal distribution across the three household groups.
- Usage distribution: determines the amount of energy low-usage and high-usage households consume relative to standard household (e.g., value of 0.5 means low-usage household consumes 50% of standard household and high-usage household consumes 150% of standard household).
- Demand distribution: determines the amount of demand by low-usage and high-usage households relative to standard household.

Note: Only change input values highlighted in yellow.

Inputs

		Units
Revenue Requirement	120,000,000	($/yr)
Households	100,000	(households)
Average Household Usage	1,000	(kWh/mo)
Average Household Max Demand	5.00	(kW)
Distribution (Households)	1/3	
Distribution (Usage)	0.50	
Distribution (Demand)	0.40	

Costs

Fixed	25%
Variable	25%
Demand	50%
Total	100%

Revenues

	With two-part rate	With three-part rate
Fixed	10%	25%
Variable	90%	25%
Demand	0%	50%
Total	100%	100%

Rates

	With two-part rate	With three-part rate	Units
Fixed Charge	10	25	$/mo
Fixed Cost	25	25	$/mo
Variable Rate	0.09	0.025	$/kWh
Variable Cost	0.025	0.025	$/kWh
Demand Charge	-	10.00	$/kW
Demand Cost	10.00	10.00	$/kW
Annual Avg Revenue per Customer	1200	1200	$/yr
Monthly Bill	100	100	$/mo
Months	12	12	months

Cross-subsidy Illustration Model

Illustration of cross-subsidization due to two-part rate (per customer)

Customer Class	Monthly Usage (kWh)	Demand (kW)	Load Factor	Fixed ($/mo)	Variable ($/mo)	Demand ($/mo)	Monthly Bill ($/mo)	Yearly Bill ($/yr)	Number of Households	Total to Utility ($/yr)
Standard household	1,000	5.00	27%						33,333	
Revenue				10	90	-	100	1,200		40,000,000
Cost				25	25	50	100	1,200		40,000,000
Over (Under) Payment				(15)	65	(50)	-	-		-
Low-usage household	500	3.00	23%						33,333	
Revenue				10	45	-	55	660		22,000,000
Cost				25	13	30	68	810		27,000,000
Over (Under) Payment				(15)	33	(30)	(13)	(150)		(5,000,000)
High-usage household	1,500	7.00	29%						33,333	
Revenue				10	135	-	145	1,740		58,000,000
Cost				25	38	70	133	1,590		53,000,000
Over (Under) Payment				(15)	98	(70)	13	150		5,000,000
Total				(45)	195	(150)	-	-	100,000	120,000,000

Illustration of removal of cross-subsidizationd due to three-part rate (per customer)

Customer Class	Monthly Usage (kWh)	Demand (kW)	Load Factor	Fixed ($/mo)	Variable ($/mo)	Demand ($/mo)	Monthly Bill ($/mo)	Yearly Bill ($/yr)	Number of Households	Total to Utility ($/yr)
Standard household	1,000	5.00	27%						33,333	
Revenue				25	25	50	100	1,200		40,000,000
Cost				25	25	50	100	1,200		40,000,000
Over (Under) Payment				-	-	-	-	-		-
Low-usage household	500	3.00	23%						33,333	
Revenue				25	13	30	68	810		27,000,000
Cost				25	13	30	68	810		27,000,000
Over (Under) Payment				-	-	-	-	-		-
High-usage household	1,500	7.00	29%						33,333	
Revenue				25	38	70	133	1,590		53,000,000
Cost				25	38	70	133	1,590		53,000,000
Over (Under) Payment				-	-	-	-	-		-
Total				-	-	-	-	-	100,000	120,000,000

Input	Value	Units
Revenue Requirement	120,000,000	($/yr)
Households	100,000	(households)
Average Usage		
Low-users	500	(kWh/mo)
Standard-users	1,000	(kWh/mo)
High-users	1,500	(kWh/mo)
Load Factor		
Low-users	23%	%
Standard-users	27%	%
High-users	29%	%

	Revenue Structure	Cost Structure	Rate	Cost
Fixed	10%	25%	$10 / mo	$25 / mo
Variable	90%	25%	$0.09 / kWh	$0.025 / kWh
Demand	0%	50%	-	$10 / kW